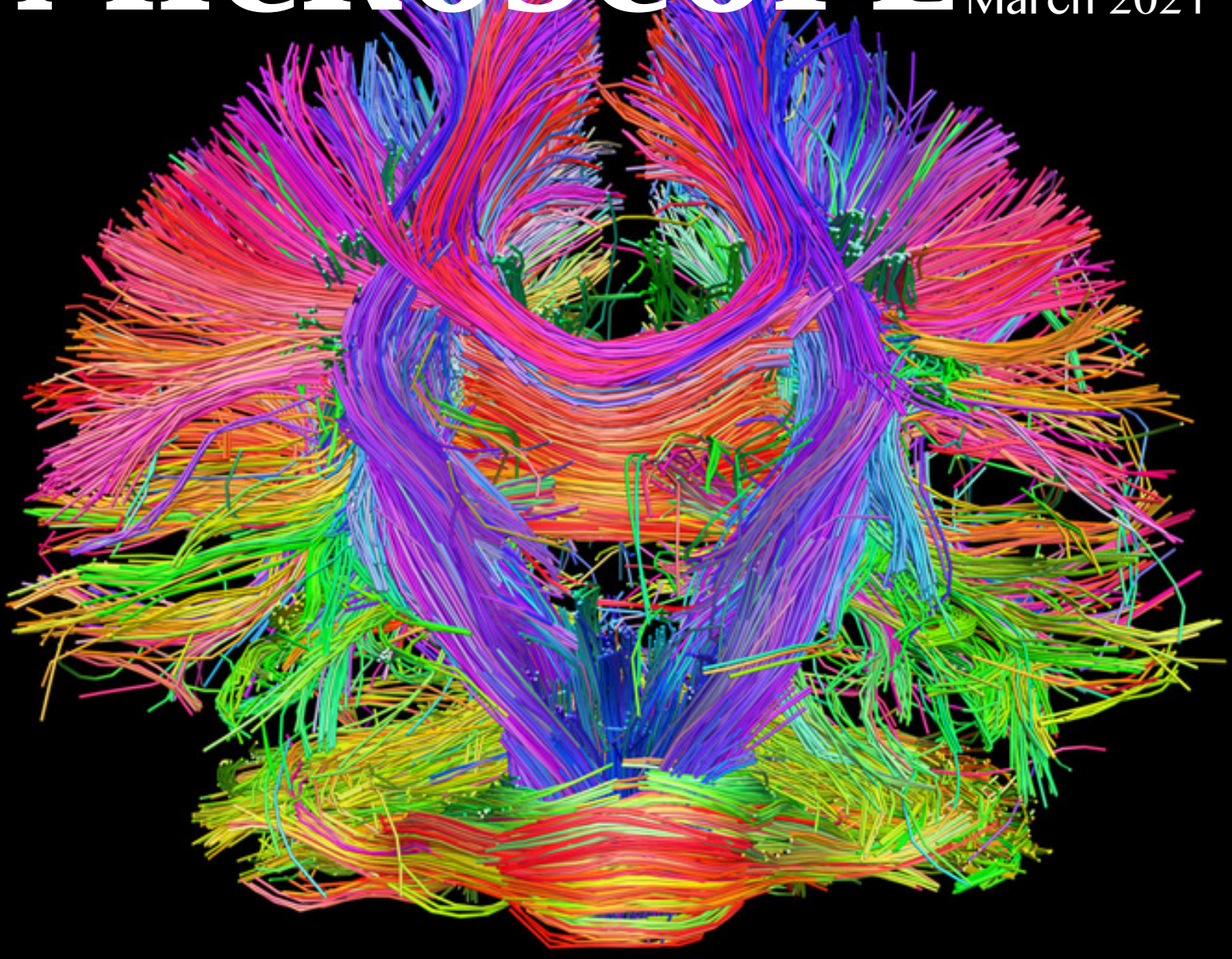
Under the Microscope

March 2021



Issue 1

Progress

image of brain mapping | credit- the human genome project

Editors note

Welcome to the first issue of Under the Microscope! We wanted to create a STEM magazine so that people in all years could get involved in STEM and develop more of an interest in it. We hope that by introducing this magazine, people will widen their knowledge and find niches that interest them. We have had so much fun creating Under the Microscope and hope you have just as much fun reading it!

- The editors

meet the editors

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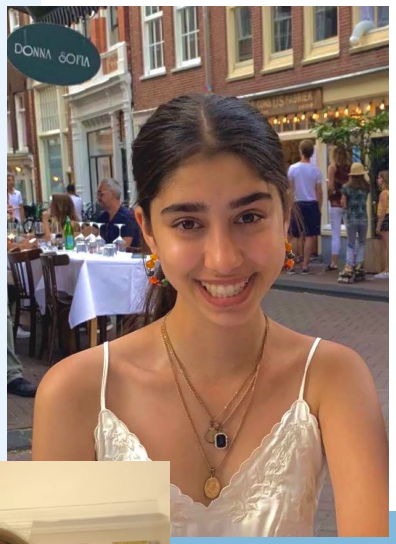

Maya Mohammad

Sarah Hazell

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The progress of Medicine – Pharmacogenomics

By Jess Butland

In the field of medicine, new advances and developments must constantly be taking place in order to treat ongoing and emerging diseases, as well as improve quality of life for patients who suffer from diseases which may not be curable. I wanted to explore a relatively new field of medicine known as pharmacogenomics, which focuses on how a persons' genes respond to certain drugs. It combines the study of pharmacology and genomics in order to tailor a drug treatment to a person's genetic makeup which is a form of personalised medicine. This is an excellent example to demonstrate how medicine is constantly progressing in order for doctors to find the right drug which has the greatest chance of helping the patient with the least number of adverse risks or side effects.

Once a person has ingested a drug it is metabolised by the body. Your proteins are responsible for breaking down and absorbing the medication and therefore affect how well the particular drug works. By analysis of the genes that DNA produces in a person, researchers are able to tell if certain proteins result in chemical changes that would make a drug less effective or cause unwanted side effects. By understanding how these genes affect the action of a drug can aid doctors in accurately determining which drug and at which dose is best for a specific patient.

In order to determine the genetic factors that influence an individual's response a scientist must study a person's genome. A genome is an organism's complete set of genetic instructions. In humans this is roughly 300,000,000 base pairs long and packaged into 23 pairs of chromosomes. By analysing the genome, researchers hope to identify changes in the DNA which may increase an individual's risk of developing a certain disease. In 1990 an international biological research project was launched with the goal of sequencing the human genome for the first time. This is called the human genome project and was aimed to make available for public viewing. This can enable researchers to try and compare human genomes to understand genetic variation and work out which variants are important in our susceptibility to disease and response to medicines.

It was found that there are two main types of variation that affect the human genome the first being single nucleotide polymorphisms (SNPs) where a change to a single base nucleotide occurs causing variation. The second is called structural variation where an entire chunk or DNA changes which can then alter the structure of the entire chromosome. In order to use this knowledge to identify a disease variant, scientists compare the genes of a group with the disease against a control group who don't have it. By doing this, it is made apparent which genetic variant is common amongst the diseased group.

The concept of pharmacogenomics is already being used in many different areas of medicine including in the treatment of many cancers and autoimmune diseases. This is really effective as cancer treatments can be very expensive and if certain drugs are only effective in a small number of individuals then it can be a waste of time and money. For example, in around 30% of all breast cancers the HER2 gene has a mutation which can be shut down by the drug Herceptin. By analysis of the tumour and treating individuals with the mutation with this specific drug then the deaths from HER2 cancer can be reduced. Acute Lymphoblastic Leukaemia (ALL) is a cancer of the blood and bone marrow. Patients with ALL can be prescribed with the chemotherapy drug mercaptopurine. However, some individuals are affected in their ability to process and absorb the drug bases on their genetic makeup. Therefore, an individual must be given a specific dose in relation to their genes to ensure there is no risk of infection or side effects. Pharmacogenomics can also be useful in some auto-immune diseases such as Crohn's disease. Thiopurine methyltransferase testing (TPMT) is a common test for patients who may be a match for thiopurine drugs. TPMT enzymes break down the drug and so if an individual is deficient in these enzymes high concentrations of the drug can be harmful. Therefore, if a person is found to have a TPMT deficiency the patient would need to be administered a lower dosage.

Not only is this field of medicine extremely interesting, as an aspiring medic myself, but also extremely relevant, as my Grandfather, who is currently on a ventilator at Chelsea and Westminster hospital with Covid-19, is about to participate in a GenOMICC research study involving people with Covid-19 and other severe illnesses such as influenza and sepsis. The chief investigator on this study is Dr J K Baillie, and his aim is to find the genes that cause some people to be more vulnerable and therefore develop better treatments for patients in the future. GenOMICC is a collaboration of doctors and scientists who are trying to better understand critical illnesses. They have partnered with Genomics England for the analysis of a single blood sample that will be taken from my Grandfather, as well as many others who are participating in the research study. These will then be analysed by researchers and compared with the DNA and health data from the rest of the population to find patterns about how diseases affect people and potentially find causes for the factors that affect how mild or severe a disease is.

If the aforementioned information is discovered about the patient's health patterns using their DNA, it could significantly help doctors treat patients who become critically ill in the future. This is a great example to show how, in the field of medicine, scientists and doctors are always striving for progress and development for the future of treatment in order to help patients in the best and the most effective way possible.

I love trees, and you should too.

By Flo Jarvis

For my article in the first ever issue of the STEM journal, I wanted to talk about trees: why they matter and what's happening to them.

So, let's start with the former. It's pretty unrealistic to attempt to capture in an article all the things that trees can do, but let's try - starting with air pollution. Air pollution, for context, is the greatest environmental health risk according to the WHO; it's already confirmed to cause nearly 30,000 deaths a year in UK (and the true figure is likely to be much higher than that), as well as being expected to reduce the life expectancy of everyone in the UK by 6 months (Defra 2015a). Trees, however, could hold the key to the solution to this deadly problem, because trees can intercept and absorb airborne particulates, especially PM10 (particulate matter of 10 micrometres or less in diameter), but also ozone, SO_2 and NOx (nitrogen oxides). Indeed, it's been found that a single tree can reduce PM concentration by 15-20% (Mitchell and Maher 2009), although the figure falls to <5% in highly polluted areas. The location and species matters: a study in Lancaster found that installing a line of young silver birch trees outside a row of houses on a high-traffic street reduced PM levels by greater than 50% inside the houses (Mahler et al. 2013), but trees with a large leaf surface area can remove 60-70 times more gaseous pollutants per year than those with smaller leaves (Salmond et al. 2016). So the research on this handy property of trees is very promising!!

The second important facet of trees' function to address is carbon sequestering. As well as drawing CO_2 out of the atmosphere for photosynthesis, trees store carbon in their wood, and the planting of trees also leads to a gradual accumulation of carbon in the soil. Once mature, carbon constitutes approximately 50% of the dry mass of trees and, crucially, this carbon is only released back into the atmosphere when the wood is burnt. This means that, by the measurements of one study, 76 billion tonnes of carbon are stored in the Amazon rainforest, for example (Helmholtz Centre for Environmental Research, 2018).

Other ecological benefits of trees include their abilities in microclimate influence, flood alleviation (their roots and crown slow rainfall), noise regulation, erosion control, shade provision (which can reduce temperatures in heatwaves), pest control, oxygen production and wildlife support. A single

400 year old oak can support more than 2,000 bird, insect, fungus and lichen species, as well as producing 234,000 litres of oxygen each year.

There is also a wealth of evidence to demonstrate the social benefits of trees: reducing crime rates (one study found that for every 10% increase in tree canopy cover, there was a 15% decrease in the violent crime, and a 14% fall in the property crime rate - Gilstad-Hayden et al. 2015), improving wellbeing, and even nudging consumers to spend more on tree-lined streets!

So what's the problem then? The problem is that the UK is developing a worrying habit of cutting down trees. The UK is already one of the least densely wooded countries in Europe (with 13% average coverage compared with an EU average of 38%). Yet, figures obtained under freedom of information requests show that more than 150,000 trees have been removed since 2010 (and that's just those removed from urban highways) - this works out at around 60 trees each day!! There is a particularly bad problem in cities, which is worsened when you consider that 84% of the UK's population lives in an urban area, and it's looking like it is set to get worse. For one, the government's HS2 project is the biggest deforestation programme the UK has seen since the Second World War, set to destroy or irreparably damage 108 ancient woodlands, 693 wildlife sites, 33 Sites of Special Scientific Interest and 5 Internationally Important Wildlife Sites. Yes, you read that right. For another, it seems like the already flimsy planning permission regulations that protect some trees are set to be relaxed in the name of economic recovery after COVID, allowing yet more trees to be cut down, or for mature trees to be cut down but replaced with a young sapling - as if that makes any ecological sense!!

It's clear to see, then, that despite their truly miraculous properties, our trees are under threat! We need experts from the STEM field to be in advisory positions, and someone needs to give Wandsworth Borough's Councillors a lesson in the basics of the carbon cycle!

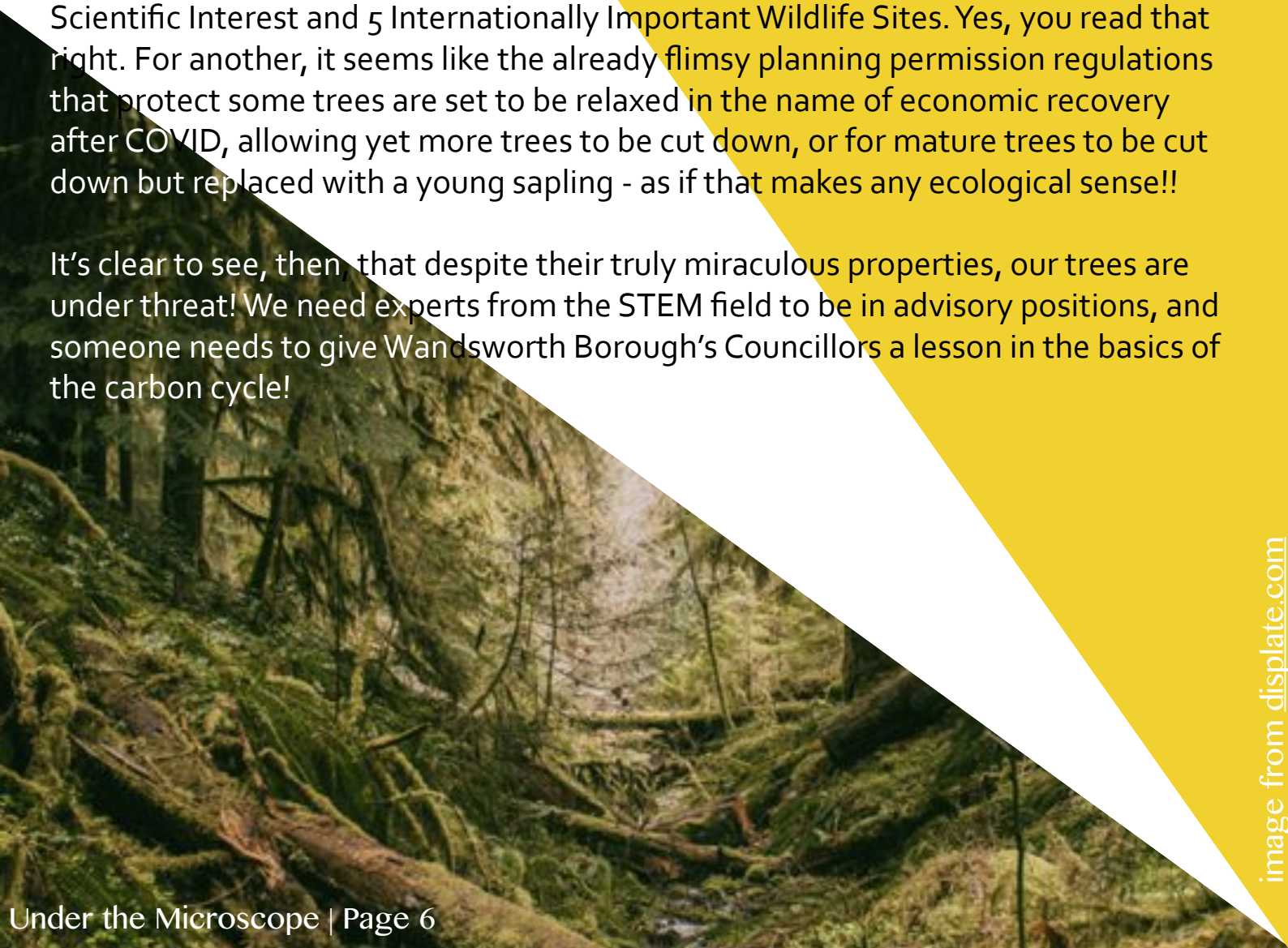


image from displate.com

The solar powered Sea Slug

By Sarah Hazell

Since the first classification of the five kingdoms, it has been an accepted fact that photosynthesis is almost completely limited to plants, some bacteria and chloroplast-containing protoctista. However, like with classification of any kind, be that biological or in everyday life, there are always exceptions.

Native to the salt marshes and inlets of the east coast of the United States, the emerald green sea slug (*Elysia chlorotica*), although unheard of, is arguably one of the most biologically interesting American marine animals. Averaging between just one and six centimetres in length and with a lifespan of roughly a year, this slug is best known for its incredible ability to filter the chloroplasts from the cells of algae and harness their photosynthetic power in a process called kleptoplasty.

In order to separate the chloroplasts in algae from the rest of the contents of the cell, *Elysia chlorotica* feed by puncturing the algal cell wall with their spiney tongues and sucking out the organelles, then eventually separating them in the gut and only retaining the chloroplasts. Through phagocytosis (the engulfing of matter into cells), these chloroplasts are then spread evenly throughout the cells of their extensive, maze-like digestive system. This gives the slugs their characteristic bright green colour compared with the natural brown which we see in their larvae stage.

Once obtained, the chloroplasts in their gut cells can last for many months, producing chlorophyll and continuing to carry out photosynthesis before dying and being replaced by others. This would seem almost impossible as the essential proteins required by the chloroplasts of the algae to survive cannot be produced by the slug's cells. However, some recent genetic research has shown that *Elysia chlorotica* could be capable of horizontal gene transfer (transferring genetic material by means other than reproduction) and therefore able to access the algae's genetic material and ultimately synthesise the proteins for its chloroplasts. This would be highly exceptional as animal-plant horizontal gene transfer is incredibly rare.

Unfortunately though, this research has not been confirmed and other scientists believe that the chloroplasts are being kept functional without the algal DNA.

On top of being able to photosynthesise and possibly being able to claim the DNA of plants, these remarkable creatures have also evolved physically in the same way that many leaves have. *Elysia chlorotica* have become broader and thinner (physiologically very different from most other species of sea slug) which increases their surface area for photosynthesis to occur in the same way that it does for leaves. *Elysia chlorotica* also have an almost ovular shape which comes to a point, and a proportionally small head which can be visually compared to the shape and stem of a leaf. As well as these evolved characteristics being for photosynthesis, the structural resemblances to leaves help to camouflage the sea slugs from predators. Remarkably, it is not only their external structure that can be compared with leaves; their internal structure such as their large, branched digestive system has evolved to be structurally very similar to the veins and midrib of leaves as well. All of these undeniable similarities are particularly astonishing because convergent evolution between kingdoms sounds unfeasible and almost leads us to question whether this slug, in some minor aspects, could be called more plant-like than animal.

Although no one is yet sure how much energy from their stored chloroplasts these sea slugs are actually reliant on and we are left to wonder whether these chloroplasts are even working at their full capacity. However, even if in the future it's found that these slugs aren't quite as magical as we want them to be, something can still be said from an evolutionary perspective about the copycat way that these slugs have evolved to be so visually similar to leaves, and for their ability to steal and retain algal chloroplasts in their own cells. Hopefully in the future these questions about these seemingly super-slugs will be answered and we will know the full photosynthetic capability of this solar powered organism.

images from: algae world news, biocyclopedia

Genome editing: For better or worse?

By Ghazal Ershadi-Oskoui

The structure of DNA was discovered in 1953, and since then our understanding of it has been evolving considerably as days pass by. Use of this knowledge has also been immense in many ways. Despite the surrounding ethical issues, the acquired knowledge represents one of the biggest endeavours in the history of medical science. Genetic alteration needs a lot of time and effort, but emergence of CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) Cas9 (an enzyme), has accelerated this process. The technique allows rapid genetic modification of almost any organism, including our own. In short, it uses bacterial enzymes to cut genomes at a highly accurate scale for which replacement genetic material can be inserted into the genome. Reports also indicate that use of this technology is quick, easy and cheap to run in almost every scientific lab around the world.

This article investigates the efforts put into genome editing technology. Genome editing technology is expected to help us live long and healthy lives with fewer diseases for future generations. However, there are also some ethical issues with genome modifications in human that must also addressed. Undoubtedly, over the recent years, genome editing has become a breakthrough in modern medicine. CRISPR was first found in bacteria, enabling the DNA to destroy viruses by storing memories from past infections in their own genome in order to recognise viruses in the event of a re- infection. Cas9 is an enzyme that can cut DNA, which may sound dangerous, but in fact our DNA is also constantly being cut, as our cells have evolved with the ability to repair broken DNA. CRISPR-Cas9 allows us to edit genomes to prevent life-threatening diseases along with teaching us more about how cancers progress and revealing promising new drug targets. It also enables researchers to edit the genome of eukaryotic cells (cells with a nucleus) more precisely and efficiently compared with other methods [Zfn & Talen], [Md. Niuz Morshed Khan, 2020]. CRISPR-Cas9 has also opened up the possibility of "designer babies" (babies that have had their genes edited), which has in turn brought up many issues.

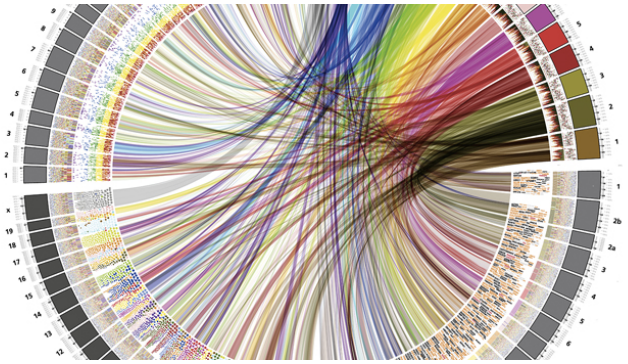
Life-threatening diseases such as sickle cell anaemia, cystic fibrosis and Huntington's disease are all caused by genes. By being able to edit these genes, the idea of curing these diseases has become very close to a reality. In addition, there is even the possibility that ageing could be stopped, prevented or even reversed, which would result in a reduced number of age-related deaths. With the use of CRISPR-Cas9, immune cells can be edited to make them better cancer-hunters. Therefore, there is an opportunity to improve the quality of life for many people who can now have life-changing treatment.

However, great power also seeks great responsibility. Several studies have shown that genome editing can create genetic errors, such as "off-

target" and "on-target" effects, leading to unexpected and unpredictable outcomes in the resulting Genetically Modified Organism (GMO) [Jennifer A . Doudna and Samuel H . Sternberg, 2017]. Genome editing raises a lot of social and ethical issues and "designer babies" is an example of an extremely controversial one. By creating the first genetically engineered baby (for medical purposes), the door opens to allow characteristics such as hair, eye colour and even intelligence also to be altered. When genome editing is done in an adult or child, the edited gene dies with its bearer, but if it is done in an embryo, the edited gene will be passed on and this could change humanity in unpredictable ways. On the other hand, looking at it from an ethical point of view, the question of consent is raised. Will future generations even want their genomes to be edited? Scientists now have the ability to permanently change the genes of future generations and it is impossible to be absolutely certain of the ways in which this change takes place.

Accessibility is also an issue that is raised by CRISPR-Cas9. Whilst ensuring that this technology is accessible to all, we must also bear in mind the hazards regarding safeguarding. By increasing the accessibility of CRISPR-Cas9, we are also increasing the risk that it shall be placed into the wrong hands. For example, just like how mosquitoes can be genetically engineered to prevent them from spreading deadly pathogens to humans, a bioterrorist could take advantage of this and make toxin-bearing mosquitoes and spread them in the wild using the same technique. Another example: if totalitarian regimes were to get hold of CRISPR-Cas9 technology, they could use it to increase their power by editing genes for their own good. For example, they can edit genes to make the next generations more athletic (useful for military purposes). Or, if this had been available during Nazi times, embryos would probably have their genes edited in order to only be of the Aryan race. This would be an example of an extremely negative misuse of such useful technology and would be morally wrong. Therefore, certain regulatory measures need to be put in place to ensure the safety of the general public is maintained.

To conclude, genome editing is great progress in the world of medical research. Regular advances in CRISPR-Cas9 technology will allow its therapeutic use for treating life-threatening diseases (such as cancer) in clinical patients that will save lives. A lot of positive changes can come from genome editing and, with the correct legal measures, it could be one of the greatest discoveries of our lifetime. Furthermore, there is a moral limit to how much we can manipulate the human genome, and this must not jeopardize the continued existence of mankind. That being said, CRISPR-Cas9 is an example of ground- breaking technology that has the ability to change the way diseases are treated in the future; it would be a shame if this technology was not put to good use.



genome image from wired.com

BY AMANDA NEILSEN

THE ERADICATION OF SMALLPOX: *What can we learn?*

In the midst of the Cold War, mankind accomplished one of its greatest achievements when it succeeded in eradicating smallpox. The WHO international website defines smallpox as “an acute contagious disease caused by the variola virus”, and it is believed to have been present in societies since Ancient Egyptian times. Smallpox presented a great problem to the world, not only for the number of deaths it caused, but also because of the psychological impact it had on patients. Patients with smallpox first developed rash lesions, which developed into vesicles, then pustules. These would then scab. The visual appearance of the symptoms, as well as the smell of pus and blood coming from the patients, deferred others from approaching them and thereby ostracised them. Even if the patients recovered, this isolation persisted throughout their lives as a result of recognisable pock-marks and scarring left from the disease, especially facial scarring. With a mortality rate of 30% in unvaccinated people and 300 million people dying from smallpox in the twentieth century alone, the world decided that it was time to make a final push to eradicate smallpox once and for all. Consequently, in 1967, a global program for the eradication of smallpox began.

By the 1960s, many western and/or developed countries had either stopped or were on the path to stopping the transmission of smallpox in their countries. On the other hand, there were other countries where smallpox was something people accepted as part of their daily lives. Therefore, the WHO placed a particular emphasis on the programme in Africa and Asia, where smallpox was still endemic. For example, India was one of the worst affected countries at the time the programme began; it is estimated that in 1967 alone, there were 830,000 cases of smallpox. With India having a high density population, as well as a warm climate, it is clear how a disease could easily be transmitted. Other challenges faced by workers involved in the smallpox eradication programme included civil war in Africa, Cold War tensions, for example between workers, and other problems such as communities not wishing to be vaccinated based on religious, cultural, or other reasons.

In previous attempts to stop the transmission of smallpox, the primary method used had been mass-vaccination. Indeed, this was also the primary method utilised during this eradication program; it was comfortable, familiar and proven to give results. However, the sheer volume of people getting smallpox and the rate at which the disease was being transmitted meant that another method was also adopted, called surveillance and containment. The basic analogy of this concept is: an outbreak is discovered (through reports or runners/searchers), people in the same household and people who have been in contact with the patients/living nearby are vaccinated; this stops the chain of transmission, thereby preventing the spread of smallpox any further. A metaphor used in the book House on Fire: the fight to eradicate smallpox, which sums up the reason behind surveillance and containment is: if a house is on fire, you wouldn't throw water on surrounding houses in case they too caught fire. Instead, you would throw water on the house on fire to prevent the fire from spreading. However, this method cannot simply be applied to all locations, even for the same disease. The approach taken for each different location when trying to eradicate a disease must be based on the context, culture, and population size. It is essential to mould the techniques known, to fit the area being targeted, in order to achieve the results you want. Every geographical location will be different.

So why is it that smallpox could be eradicated and other diseases have yet to be? In fact, smallpox was the first disease to be eradicated, with rinderpest being the only other disease to be officially eradicated since (as of June 2011). Firstly, and very importantly, smallpox is an easily recognisable disease due to the obvious symptoms displayed by patients. This meant that workers/searchers for the eradication programme could travel around with photos of what a patient with smallpox looked like, showing them, for instance in schools. They could then be informed of any nearby smallpox cases. Additionally, smallpox does not affect any non-human species, which meant that attention did not have to be paid to stopping transmissions in other species, allowing scientists and workers in the eradication programme to focus on humans.

So, what are the key messages to take away from the eradication of smallpox? A major lesson is definitely to be more optimistic. Without optimism, eradication wouldn't have been possible. Surveillance revealed a

lot more cases of smallpox than originally thought. This could easily have led to a loss of hope and enthusiasm, causing the program to decline in productivity and success. However, the people working on the programme realised that the “increase” in cases just showed that surveillance was working, and that more outbreaks were being discovered rather than being allowed to grow undetected. Smallpox couldn’t have been eradicated if those working on the programme didn’t know the locations of outbreaks and how severe each outbreak was. Another message to take away is that we must always be respectful and aware of cultural differences and opinions. People can have many reasons to be cautious towards strangers intruding on their lives. Even though this wasn’t a massive problem in the case of smallpox, as many people feared the disease and so were more likely to co-operate, it is still worth noting that the positive response to the smallpox eradication programme from the majority of the public, will not necessarily be the same in other situations. We should listen to different people’s views and reasons for not wanting to participate in a vaccination/eradication programmes, and always try to make sure they receive all the relevant information needed, in order to give them the ability to make their own informed choice. Finally, smallpox eradication wouldn’t have been achieved without the special epidemiologists, searchers, physicians and other workers, from all over the globe working together for a common cause. In addition, the resources provided by countries to others was essential. For instance, the USSR promised even before the start of the programme, in the 1959 meeting of the WHO, to donate 25 million vaccines to the cause. Teamwork is essential.

In conclusion, the eradication of smallpox was a historic and momentous occasion for not only science but for humankind in general, as a prominent threat to global health was eliminated. The last known natural case of smallpox occurred in Somalia, in 1977, and the WHO officially announced the eradication of smallpox on the 8th May 1980. Currently living through a pandemic, it is interesting to see the experience gained during the course of the smallpox eradication programme, put into practice. This can be seen in the form of strategically vaccinating the most vulnerable first, as well as adapting the method of surveillance and containment into lockdowns and track-and-trace. However, as mentioned before, each disease and/or virus is different, and we must all adapt and work together to overcome the challenges we have been living with for the past year.

WHAT ARE SPACE STORMS?

BY BEATRICE CRACHILOVA

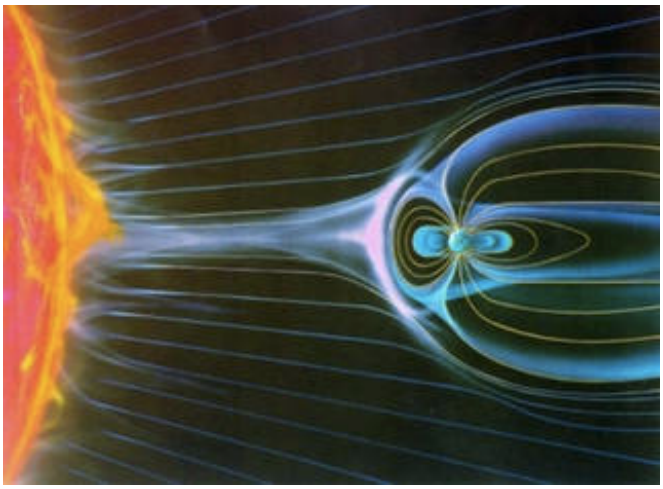


image from NASA

In usual satellite imagery, you will see a hurricane as a collection of clouds circling an eye. But if storms happen in space this is shown totally differently. The first space hurricane to be spotted was in august 2014, where satellites noticed it above the north pole. The main difference between storms on earth and storms in space is that storms in space are made up of plasma and gas and instead of releasing rain, in space it releases electrons.

The recent space hurricane lasted 8 hours swirling anti-clockwise. Scientists were trying to find out what caused it and concluded that charged particles emitted by the sun's upper atmosphere, the corona, were to blame. This steady stream of solar particles and coronal plasma is known as solar wind. It moves at about 1 million miles an hour.

Magnetic fields don't always combine. However, if they get close enough, parts of the fields will realign and even combine, creating a new magnetic energy pattern. On the day of the space storm, this is most definitely what happened: A new trend emerged above Earth's magnetic north pole as a result of an explosion of solar wind energy.

This particle rain may have caused chaos on our high-frequency radio signals, radar detection systems, or satellite technologies, according to the authors of the report. This is because the charged solar particles that run through the Earth's magnetic field can cause malfunctions in computers and electronics on satellites and the International Space Station. Luckily, no complications have been found in this situation.

Sensory substitution: The progress we've made in terms of understanding how the senses work

By Alessia Lowcock

Our brains exist in complete darkness; they do not directly interact with the world around them. In fact, all our brain ever "sees" is electrochemical signals. This means in order for our brain to perceive the world around us, it needs the help of sensory organs (eyes, ears, etc) to detect incoming information from the environment. Humans have 5 fundamental senses: sight, sound, smell, touch, and taste. However, this is obviously not the case for all animals. Different animals in the same ecosystem pick up on different environmental signals, and each organism presumably assumes its objective reality to be all that there is "out there". Humans are a great example of this: we have the sense of sight, yet it is very uncommon knowledge that we can only view a ten-trillionth of the entire electromagnetic spectrum. If we were not taught that other forms of light existed, we would most-likely assume that we were seeing all there was to see. This idea of objective reality, and the boundaries of natural senses, is synonymous with the scientific term "umwelt", meaning "environment" or "surroundings" (first introduced by biologist Jakob von Uexküll in 1909).

Our umwelts and arguably pitiful experiences of reality are constrained by our biology. We accept reality as it's presented to us, and are firmly settled into our umwelts. This, therefore, presents the questions: do we have to be stuck there? What if there was a way, through the use of technology, that we could expand our umwelts? In neuroscientist David Eagleman's Ted Talk 'Can we create new senses for humans?', he discusses these questions, and explores how we can teach the brain a new sense through 'sensory substitution'.

Sensory substitution is a non-invasive scientific technique used to transform the stimuli of one sensory modality into stimuli of another sensory modality. Put simply, this means to use one sense to gain information that a different sense would normally receive. An everyday example of this is blind people using their sense of touch to read braille.

The idea of sensory substitution was first introduced in the 1960s by Bach-y-Rita, an American neuroscientist who worked within the field of neuroplasticity. Bach-y-Rita focused on tactile sensory substitution, the technique of using a person's sense of touch to compensate for another sense, and he went on to design the first sensory substitution device as

a means of brain plasticity in congenitally blind people. In 1969 Paul Bach-y-Rita and several of his colleagues published a short article titled 'Vision substitution by tactile image projection' which detailed the workings of his sensory substitution device. The device itself was a metal plate attached to the back of a modified dental chair consisting of 400 vibrating solenoid stimulators. A camera connected to the plate was placed in front of the subject for them to manipulate as it constructed a video feed of the room. These images were then translated into vibrational patterns onto the skin of the subject's lower back. After approximately 1 hour of training the subjects were introduced to twenty-five common objects, and eventually the delay between "seeing" the objects and recognising them fell considerably. In the process, subjects familiarised themselves with many visual concepts including perspective, shadows, and discriminating overlapping objects. With more practice, patients were even able to differentiate between individuals, describing their posture, movement, and individual characteristics. While recording the latency and accuracy with which subjects were able to detect what was being presented to them, what Bach-y-Rita came to find was that blind individuals performed at a remarkably high degree of accuracy (despite their training experiences ranging from only 20-40 hours!)

Since this invention, sensory substitution has been the focal point of many studies investigating perceptive and cognitive neuroscience. Through the help of developing technology and innovative ideas, several fascinating sensory substitution devices have been made. One recent example Eagleman gives in his Ted Talk is a low-cost vibratory vest of his own invention that allows those with deafness or severe hearing impairments to perceive auditory information through small vibrations on their torso. What makes these devices really exciting is the brain figures out how to interpret these signals unconsciously. If we take Eagleman's vest for example, the vibrational patterns are too complicated to process and work out step by step, so the individual learns to recognise these signals without conscious intervention.

What sensory substitution has taught us about our senses is that when a person becomes blind or deaf they generally do not lose the ability to hear or see; they simply lose their ability to transmit the sensory signals from the periphery (the retina for visions and cochlea for hearing) to the brain. We know this must be true as areas of the auditory cortex are still active in profoundly deaf individuals. As recently as 20 years ago there were many scientists who thought techniques such as cochlear/retinal implants wouldn't work because the "language" these technologies speak is very different from the way our brain functions. But the fact is, it does work. The brain is able to figure

out how to utilise these signals. If we apply this same principle to sensory substitution, we can explain how someone is able to get a direct perceptual experience of hearing through the sense of touch. No matter where the signals come from, our brain cleverly figures out what to do with the data it receives; areas of the brain are capable of performing specific tasks if they receive relevant information, irrespective of the sensory organ via which they receive it. If you haven't figured it out by now, this also (excitingly) means our senses are not just constricted to the ones within the human umwelt. When we apply this principle to the technology we have today, we could use it to give humans senses we've never experienced before: to see in infrared/ultraviolet, to feel the overall "health" of their vehicle while driving, to have a direct perceptual experience of the stock market and economic movements of the planet, and more!

To conclude, the biggest takeaway I would want you to gain from reading this article is the following: our brains are incredibly cool. They are constantly receiving data and figuring out how to interpret it at an extraordinarily high rate. And as long as we continue to develop the technology we use in sensory substitution, there's really no end to the possibilities on the horizon for human expansion. In the words of Eagleman himself, 'We've been given the tools from nature that we need to go out and define our own trajectory, so the question now is, how do you want to go out and experience reality?'

Key:

Non-invasive = relating to any medical test or treatment that does not cut the skin or enter the body (no surgery is required)

Neuroplasticity = the ability of neural networks in the brain to change through growth and reorganisation

Tact = Sense of touch

Profoundly deaf = completely unable to hear anything

David Eagleman sensory vest

"We accept reality as it's presented to us, and are firmly settled into our umwelts"

PROGRAMMING INNOVATION: IS AI REALLY THE FUTURE OF SURGERY?

BY MAYA MOHAMMAD

Confidence, skill, risk. Arguably the three most important words summarising the world of surgery. It is confidence that allows a surgeon to be heard, it is skill that allows a surgeon to be respected, and it is the ability to take risks that separates the good from the great. This partnered with myriad of other components effectively creates the 'recipe' for a surgeon. But what if there was a better recipe, a newer recipe? We are in the midst of a technological revolution, and with that comes a wave of new ideas with potential to change the practice of medicine. Artificial intelligence (AI) is already navigating its way into surgery through more simple things such as AI-assisted endoscopies, to surgical robots such as the da Vinci. With such great advancements in AI, one is led to question the need for humans. If we keep making progress as we are currently, it's not irrational to debate the idea of solely robotic surgeries.

The human mind is one prone to mistakes. Whilst working painfully long shifts, one can expect the occasional error to find itself on the operating table. However, the slightest fraction of error gives rise to numerous potential adverse events. A study conducted in three US hospitals found that in 5356 surgeries, 3.4% of patients experienced adverse events, 56.4% of which were due to human error. That means almost 2% of all surgeries have had some sort of adverse event happen, simply because humans make mistakes. Hundreds of thousands of surgeries take place each day, so with this margin of error, we are sitting placidly allowing thousands of people to draw the short straw of surgery. With all of this in mind, it is understandable that scientists around the world are constantly trying to find new ways to better the odds of surgery. Artificial intelligence can be loosely defined as the study of algorithms that give machines the ability to reason and perform cognitive functions such as problem solving, object and word recognition, and decision-making. Incorporating this into surgery through preoperative planning and intraoperative guidance allows for humans to be assisted by statistical and real-time analysis. The ability to program a machine to perform in a consistent manner is something unique to AI which humans frankly cannot do. Researchers in a hospital in Oxford found that 8 times out of 10, AI was able to diagnose heart disease more accurately than humans. This means that in those late hours, when the mistakes slip through the cracks, AI can provide the guidance needed to perform flawlessly.

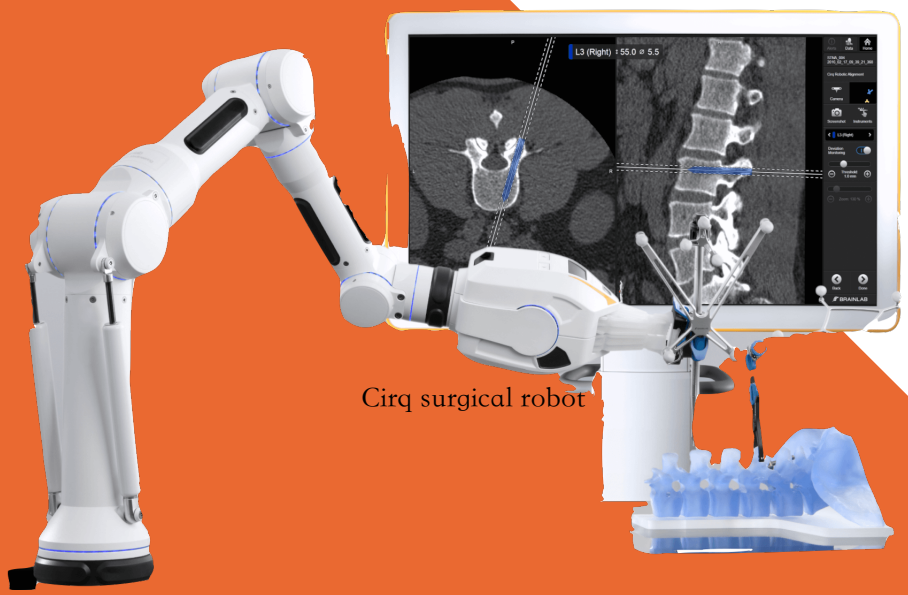
Not only can AI help humans with analysis and imaging, but also mechanically. Surgical robots are a quickly developing market and new ideas are continually being introduced. These range from robotic instruments to complete surgical robots. The DaVinci surgical system was the first surgical robot cleared for general use in 2000. It allows for a wide range of surgeries to be carried out in a minimally invasive way such as cardiac, colorectal, gynaecology, head and neck, thoracic, urology, and general surgeries. The use of robotics in surgeries is beneficial in many ways. One of the biggest benefits of surgical robots is that the surgeon doesn't need to be with the patient. Surgeries can now take place from across the globe which allows access to world leading surgeons and better healthcare without the need to travel. This has potential to revolutionise the way we treat patients today and could provide much more equal healthcare. It also has mechanical benefits. As the robotic arms are fitted with complete wrist action and have no tremor, small incisions can be made, as only these small arms need to enter the patient. This means fewer post-operative infections and quicker recovery time. It has also been shown that blood transfusion rates for robotic surgeries are near 0%, compared to the 40% for human surgeries. All these statistics point towards a realisation that robotic surgeons are seemingly much more safe; solely robotic surgeries are something of fantasy, but could they be more functional than we think? We have seen how AI has lowered margins of error and if they continue to develop at current rates, it's realistic that we will be able to program robots to perform complete surgeries, without the assistance of humans. This means consistent results and no chance of error from the surgeon, which could potentially save thousands of lives. Nonetheless, we are in such early stages of this field and already have such positive results so it seems inevitable that robots will eventually become the new surgeons.

However, one key point highlighted earlier may be the end to this futile dream - the ability to take risks. It is one thing to program a robot to do what we know, but that's not all surgery is. Surgery is about adapting to the environments and creativity, something you can't program. Professor Roger Kneebone of Imperial college once said, "Improvisation is the highest form of expertise" and this improvisation is something only the living mind can achieve. Although we may not like to acknowledge it, surgeries do not always go the way they are planned. Complications are an unfortunately common part of surgery and they aren't always the fault of the surgeon. So, when such complications arise, surgeons must have the confidence and willingness to improvise and know they will create a positive

outcome. But if these surgical robots are programmed, they cannot think in the moment and react the way a human would. This means that any new or uncommon errors that arise will not be able to be fixed, as the robot cannot be programmed to react as humans do. Similarly, the programming of AI significantly limits the abilities of these robotic surgeons. New techniques and ideas are being published daily and without human surgeons to make these discoveries, we are holding back possibly revolutionising advancements. Surgery isn't as simple as we would like it to be and until we know all the ins and outs and each possible technique, outcome and skill, we can't teach it to robots, so can't rely solely on them.

Taking all of this into account, it would be naive to say that artificial intelligence isn't the future of surgery, it definitely is. New concepts such as Surgery 4.0 ability are paving the way for an inspiring future. However, it is clear that the sci-fi fantasy version where all surgeries are performed by robots, is unrealistic and, until we can program a robot to have a human brain, it always will be.

"Surgery is about adapting to the environments and creativity, something you can't program"



Cirq surgical robot

The discovery of cortisone

By Laila Samarasinghe

Steroids play a key role in the body's response to many illnesses. They work by suppressing the immune system to control inflammation. Inflammation is the body's response to infection, bringing white blood cells to the area to fight it. However, in some autoimmune disorders the white blood cells are brought in to fight when there is no infection, only excess fat or toxins from smoking or any other abnormal substance. In these cases, steroids can be used to control the inflammation. The symptoms of around 200 diseases are radically improved by simply taking steroids, making modern medicine almost unimaginable without them. Even symptoms of COVID 19 are improved with their administration. For those on a ventilator, taking steroids decreases inflammation in the lungs, increasing the chances of survival by around a third. It was not until 1949, after almost twenty years of work, when the first steroid was discovered, cortisone.

It was Dr Philip Showalter Hench, head of the Division of Medicine at the Mayo Clinic in Minnesota, who made the first, important observations. In 1928, Dr Hench treated a 65-year-old patient who was suffering from severe rheumatoid arthritis, a condition which causes swelling and pain in the joints. Later, this patient came to develop jaundice as a result of his liver becoming inflamed. Obviously, this is a bad thing, right? Actually, no. After just one day, the swelling in his joints subsided. The patient's hands and feet, previously afflicted by rheumatoid arthritis, were completely painless for the 7 months that followed. How had this happened?

Dr Hench decided that surely, if the patient's symptoms had improved after getting jaundice, then a substance released whilst suffering from it must be what is improving the pain? He decided to name whatever this miraculous substance was 'Substance X'. So, Dr Hench proceeded to give his patients with rheumatoid arthritis things he thought could be Substance X, such as bile and blood transfused from patients with jaundice, but none of them worked. However, Hench did not give up. Soon after, he came to realise that jaundice is not the only thing which improved the pain and swelling, pregnancy improved it too. Also, rheumatoid arthritis was not the only disorder helped by these things, other disorders such as hay fever and asthma were helped too. So, Hench could assume that Substance X had the capability to help with multiple illnesses. Now all he had to do was find out what Substance X was.

Also working at the Mayo Clinic was Edward Kendall, Professor of Physiological Chemistry. He had been studying adrenal hormones and proceeded to name some of the chemicals in them Compounds A, B, E and F. On meeting with Kendall, Dr Hench began to wonder with him if one of his compounds could be the same thing as his Substance X. Unfortunately, no pharmaceutical company would risk synthesising large quantities of their compounds for them to investigate. So the pair of them were forced to accept that they could not continue their investigation together, but became good friends. So if nothing else, at least a bond had developed from the shared wish to find out about Substance X.

Now I would like you, my reader, to remember something - the last rumour you heard. Chances are it was fun or surprising, but most likely untrue. And it was a rumour which was surprising and untrue which saved Dr Hench and Kendall, in their goal to discover Substance X. In the midst of World War, a rumour that Germany had purchased adrenal glands from cattle and were using the hormones reached the United States. This rumour also said that the hormones used were allowing their pilots to fly at an outstanding 40 000 feet. Immediately, all labs with previous works associated with adrenal extracts were urged to continue research. This rumour was soon, of course, accepted as untrue. However, by then in 1948, Kendall and Hench's lab had already begun to synthesise hormones and another man, Dr Sarett managed to obtain a few pure grams of Kendall's compound E, which was discovered to be the same thing as Hench's Substance X. So we've finally found out what Substance X is! It was named Cortisone.

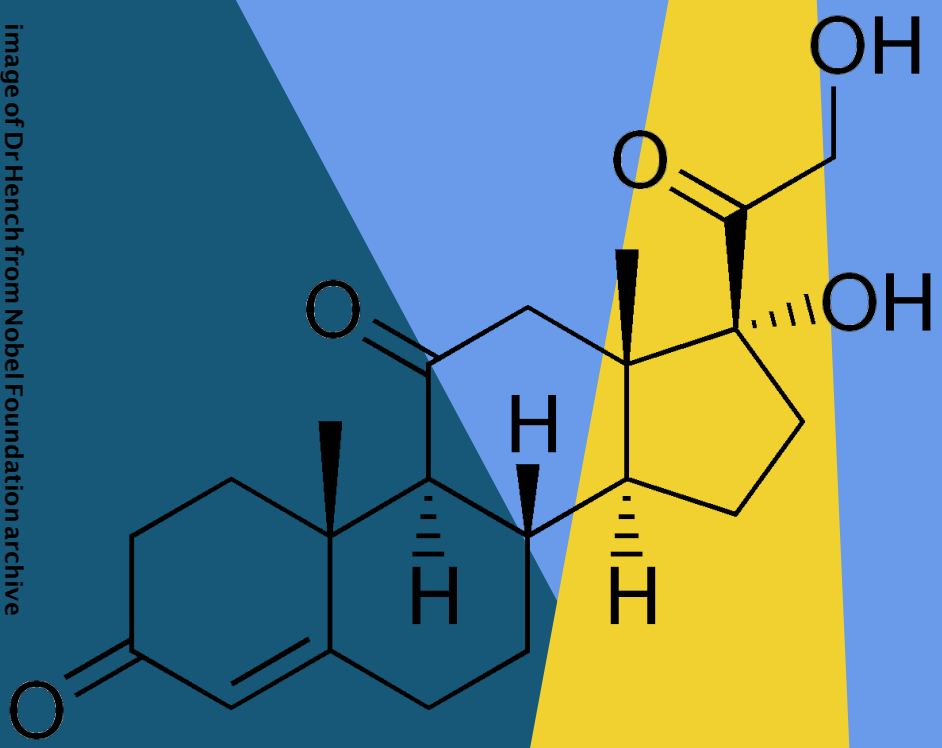
When administering cortisone to patients with rheumatoid arthritis, Hench chose to give them extremely high doses for no apparent reason. Additionally, the size of the crystals was perfect, as had they been any larger, the results would have been far less dramatic. However, by lucky chance, they did give these high doses and the crystals were the right size and the results were truly extraordinary.

According to a Times article at the time (in 1949), 'within a few days of administration patients were able to get out of bed and walk about, and the pain and the swelling of the affected joints disappeared'. It was seen as a miracle cure and, the following year, Hench and Kendall were both awarded the Nobel Prize. However, it was all too good to be true. Hench was aware that the symptoms were only gone for as long as the patient continued to take cortisone in these high doses, but taking it had severe side-effects, such as bleeding ulcers and bruising of the spine. Soon, the medical community came to lose trust in the 'miracle cure'.

However, for a wide range of illnesses which were difficult to treat, cortisone was administered, purely to see what would happen. Shockingly, by 1950, it was found that cortisone was effective in helping with many disorders such as conjunctivitis, chronic intractable asthma, systemic lupus erythematosus (an immune disorder), polyarteritis nodosa (inflamed blood vessels) and other illnesses too. Additionally, it could be given in lower doses and applied to the skin or eyes which limited side-effects. Also, unlike for rheumatoid arthritis, when used to treat these other disorders, cortisone could be used for a very short crisis and then stopped afterwards. So, although cortisone was not very effective in treating rheumatoid arthritis, it turns out it is very useful for treating other things!

Nowadays, cortisone and a range of other steroids are used all the time, playing an instrumental role in modern medicine. You have surely seen an asthmatic inhaler? Well, when they use the brown inhaler, they take in steroids to reduce the inflammation in their lungs, helping them breathe. Also, people with eczema can apply steroids to their skin to reduce the inflammation. Steroids are also effective in treating other autoimmune disorders and inflammatory issues such as swelling in the brain, and infectious illnesses. It can be said that the discovery of cortisone was extremely lucky. After all, what's the chance the Dr Hench and Kendall were both working at the Mayo Clinic, then that a rumour about German pilots would allow them to continue their work? However, even though there was a great deal of luck involved in their discovery, there was also an amazing amount of perseverance, observance and logic from Hench and Kendall, which is what has allowed us to make use of steroids every day.

image of Dr Hench from Nobel Foundation archive



Microbes:

The future for combatting climate change?

By Saskia Pearl

When googling "how could microbes be used to…", you will find that autocomplete generates a myriad of responses. These range from "how could microbes be used to help fight disease?" to "how could microbes be used to improve soil fertility?". The diversity of these responses demonstrate the versatility of these valuable yet underrated microorganisms. But exactly what are microbes? The simplest answer is that they are minute, unicellular organisms, with the most common types being: bacteria, fungi, viruses and protozoan. Microbes are much more ancient than *Homo sapiens* and have been present since the early Precambrian time, around 3.5 billion years ago. Because of this, they have evolved to live in a huge variety of habitats and have an ubiquitous influence on the planet. Some microbes are chemosynthetic, meaning that they use inorganic molecules as a source of energy and convert them into organic substances. These microbes, termed extremophiles (usually bacteria or methanogenic archaea), live in remote regions, including in 130°C hydrothermal vents at the ocean floor or deep in polar ice. Other microbes are photosynthetic, converting light energy into chemical energy. Because of the complex and varied processing systems, microbes have the potential to be a crucial factor in combatting climate change in significant ways.

Plastic waste is a notorious effect of human activity on this planet; 100 million marine animals die each year from plastic waste alone! But could microbes offer a solution to this vast and growing problem? Researchers have recently discovered a strain of bacterium, *Pseudomonas bacteria*, that breaks down toxic plastic by using polyurethane compounds as a source of carbon, nitrogen and energy. Polyurethane is a common compound used in plastic products due to its pliability and durability. In 2015, polyurethane products alone accounted for 3.5 million tons of the plastics produced in Europe. It not only decomposes slowly but also releases toxic chemicals into the soil during degradation which is why it is imperative to either halt the use of it or find a suitable way to dispose of it. Bacteria carrying out the aforementioned process could therefore be instrumental in aiding the disposal of plastic waste. However, this bacterium can only metabolise the "building blocks" of polyurethane and, consequently, will have a minimal impact on the reduction of plastic waste as they can't break down large polymers. Nonetheless, there is still hope. If one type of bacterium can break down

polyurethane, then surely there are other types of bacterium that break down different types of plastic? Additionally, with the breakthrough discovery of CRISPR Cas9, perhaps altering the genome of a particular bacterium may be possible, opening endless doors.

Speaking of genetic modification, researchers from the Weizmann Institute of Science in Israel have rewired a strain of bacteria called *E. coli*. They have altered it so its metabolic processes use CO2 to produce the majority of its mass, instead of alternate organic compounds such as sugars and fats. This involves adding genes which metabolise CO2, and removing genes which process sugar compounds. The engineered *E. coli* strain uses the Calvin cycle for carbon fixation, which is the same mechanism that plants use. Put simply, this bacterium can now extract CO2 out of the atmosphere and use it to make food for itself. CO2 is a Greenhouse gas and therefore removing it from the atmosphere, even in small quantities, could help to reduce the Greenhouse gas effect. This incredible feat provides evidence that genetically engineering bacteria could help transform waste products into food, fuel or other useful compounds. Additionally, it can improve our understanding of the molecular processes that form the basis of food production for humanity, thus enabling us to increase agricultural yields in the future.

If I were to fully elucidate all of the reasons why microbes are instrumental to mitigating the effects of climate warming, this article would be never ending. I hope the examples I have provided are evidence enough that preserving our symbiotic relationship with microbes is tremendously important. Without microbes we would never have evolved, and now we have the resources and knowledge to utilise these microscopic machines to our advantage. They can incrementally alter the climate, crop production, soil fertility, cloud coverage and many more. Essentially, our survival as a species is utterly dependent on the planet's microbial population. I believe it's best to end this article with a fitting quote from Bill Bryson's The Body:

"Make no mistake. This is a planet of microbes. We are here at their pleasure. They don't need us at all. We'd be dead in a day without them.".

A CURE FOR GENETIC DISEASES?

BY MAYA MURALI

Our body is composed of millions of cells. Each of our cells contains 2 meters of DNA (genetic material) and this is what makes you, you! You might be thinking, if our cells are so small, how can there be such a long piece of DNA packed in each of them? DNA is stored by wrapping themselves around proteins called histones. The structure that is formed when DNA wraps itself around a histone is called a chromatin. The benefits of this structure are, it's great for compacting the DNA, however, it makes the actual genetic material impossible to read, meaning the cell cannot carry out its needed function. This is why each of our cells contain chemical tags on them called epigenetic marks which can turn certain genes "on and off." For example, our muscle cells and nerve cells both contain the exact same genetic material but both carry out extremely different functions, so in a muscle cell the genetic material for a nerve cell would be switched "off" and in a nerve cell, the genetic material required for a muscle cell would be "off." Although epigenetic tags can alter which genes are turned "on or off", external environments affect genetic sequences and can influence disease. The fate of what diseases we could be diagnosed with, could be impacted by factors such as diet and stress or environmental factors.

WHAT IS EPIGENETICS?

Epigenetics is the study of changes in your environments and behaviour that can cause changes in the way your genes work or are read by your body. Epigenetic changes are reversible, which is why they could potentially help us find cures for serious disease.

HOW DOES EPIGENETICS WORK?

These 3 examples are all epigenetic processes which are considered to initiate and sustain epigenetic change. The first process is DNA methylation. DNA methylation works by adding a chemical group to the DNA. These chemical groups can block the histones that attach to the DNA, making it hard to "read" the gene. This chemical can also be removed which turns the gene "off" again. The second is histone modification which is the adding or removal of chemical tags from the gene. Again, adding or removing these tags can turn the gene "on" or "off." The final is non-coding RNA, which helps control gene expression by attaching to coding RNA along with certain proteins, to break down the coding RNA so it cannot be used to make proteins.

EPIGENETICS AND DISEASE:

When a bacteria or virus invades your immune system, changes to the structure of the histone can occur in your immune cells. This results in them turning "off" the gene. In other words, your immune cells stop fighting the pathogen. This can make you more vulnerable or exposed to dangerous, or terminal disease. Likewise, some epigenetic changes increase your cancer risk. For example, having a mutation in certain genes , prevents them from working properly, making you more susceptible to breast and other cancers. Epigenetics can be used to help determine what type of cancer a person has or help to find hard to detect cancers earlier, so as to prevent it from spreading majorly. As we mentioned previously, epigenetic marks are small chemical tags which instruct our chromatin which genes to turn on or off, meaning if we could unveil how to manipulate them, we could regulate the expression of genes which check or correct cell mutations which would otherwise lead to diseases such as cancer.

Recent and new data is proving just how crucial epigenetics is proving to be. Although drug development based on epigenetics is difficult and expensive, the reversible nature of epigenetic modifications has made therapeutic medications a possible alternative in the near future. The epigenomic data will provide a chance to discover and unlock new epigenetic marks and their effect on our genes. With the right tools and resources, we are on track to curing all genetic disease.

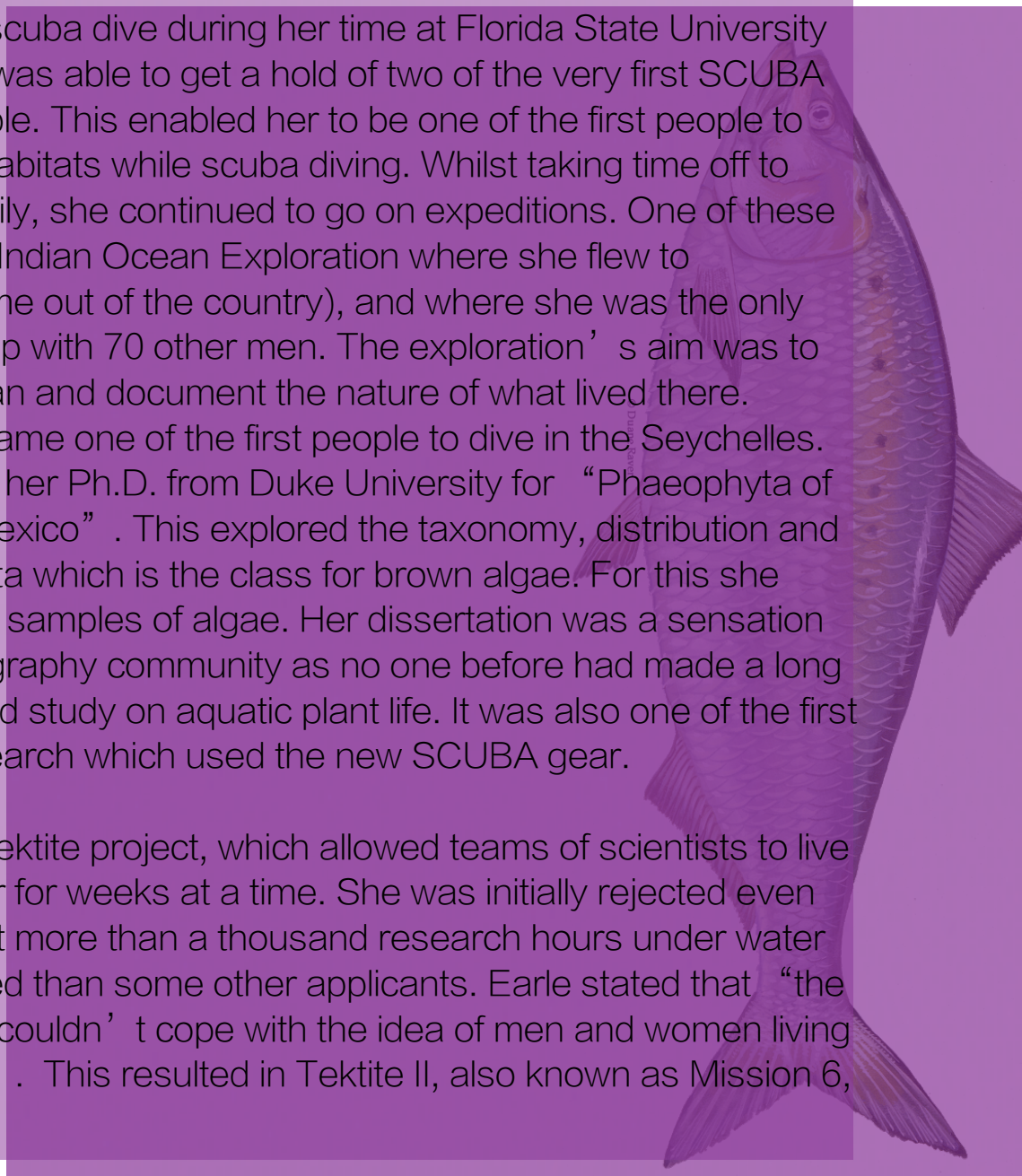
Sylvia Earle – one with the fish

By Luisa Sulzberger

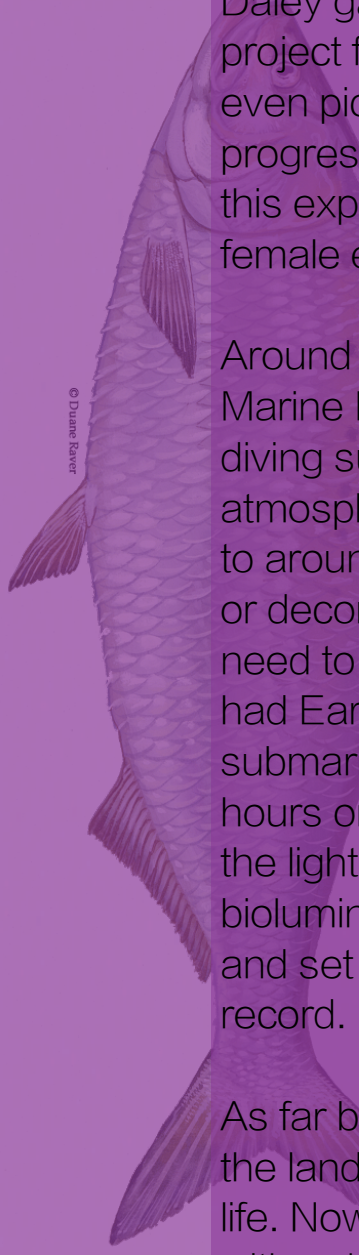
Sylvia Earle is a legend in the world of deep-sea diving and marine biology. This 85-year-old woman has set many records in the ocean, winning numerous awards and has paved a way for female researchers around the globe. Her tireless quest is to educate the world on the importance of the oceans and the importance of its health to our own survival. She was previously the chief scientist of the NOAA and in her career has discovered 26 new species. Currently, she runs Mission Blue and goes around the world giving talks as to why we should start prioritising the ocean. Her incredible achievements throughout her life have impacted not only marine science, but also women in science.

Earle first learned to scuba dive during her time at Florida State University where her professor was able to get a hold of two of the very first SCUBA sets that were available. This enabled her to be one of the first people to explore underwater habitats while scuba diving. Whilst taking time off to marry and start a family, she continued to go on expeditions. One of these was the International Indian Ocean Exploration where she flew to Mombasa (her first time out of the country), and where she was the only female aboard the ship with 70 other men. The exploration's aim was to just discover the ocean and document the nature of what lived there. Through this she became one of the first people to dive in the Seychelles. In 1966, she received her Ph.D. from Duke University for "Phaeophyta of the Eastern Gulf of Mexico". This explored the taxonomy, distribution and ecology of Phaeophyta which is the class for brown algae. For this she collected over 20,000 samples of algae. Her dissertation was a sensation amongst the oceanography community as no one before had made a long and detailed first-hand study on aquatic plant life. It was also one of the first pieces of original research which used the new SCUBA gear.

Earle applied to the Tektite project, which allowed teams of scientists to live 15 metres underwater for weeks at a time. She was initially rejected even though she had spent more than a thousand research hours under water and was more qualified than some other applicants. Earle stated that "the people in charge just couldn't cope with the idea of men and women living together underwater". This resulted in Tektite II, also known as Mission 6,



being formed in 1970. Tektite II was an all-female expedition which was led by Sylvia Earle herself and was the first team made up of only women to conduct research of this type. Tektite II was located in the Virgin Islands National Park as it was an undisturbed area with great biodiversity, including various coral reefs, seagrass beds, and sandy plains. This allowed marine scientists to study marine life's diurnal and nocturnal behaviours. Many of the studies that were carried out on Tektite I and II are still being continued and relevant in the present day. During the expedition they studied the bioacoustics of reef organisms, the influence of herbivores on the marine plants, and patterns in the behaviour of coral reef fishes, spending around 10 to 12 hours in the water per day. After the project the women in Tektite II received a parade in Chicago and Mayor Daley gave them the keys to the city, showing the importance of this project for women. Women had been seen as not able to do the job, or even pick up the equipment of the SCUBA gear. Tektite II has given great progress in ocean exploration and marine science for female scientists as this expedition has shifted the patriarchal structure, helping many more female explorers back then and even today.



Around the same time as Tektite I, the English company, Underwater Marine Equipment Limited, invented the JIM suit, which is an atmospheric diving suit designed to maintain an interior pressure of 1 standard atmosphere despite exterior pressures and can withstand water pressure to around 600 metres. This means that there is no risk of nitrogen narcosis or decompression sickness, also known as the bends, nor does the diver need to decompress when returning to the surface after a deep dive. They had Earle test the JIM suit in Oahu, Hawaii and had her attached to a submarine in case something went wrong. Earle spent two and a half hours on the seabed at 381 metres exploring the sea and when she asked the lights of the submarine to be turned off, she saw many different bioluminescent creatures. She was then untethered from the submarine and set the world untethered diving record and the woman's depth record.

As far back as 1872 the US began establishing a system of parks in which the landscape and animals are protected, but it does not apply for ocean life. Nowadays, around 15.4% of the world's land is protected, compared with only 3.4% of the ocean. Earle has created Mission Blue which aims to protect the ocean in which we protect the land. She has created Hope

Spots, in which an area has protection and recovery from anthropogenic activities. Hope Spots have to be places where there is potential and some kind of threat, meaning it needs to be safeguarded. Mission Blue was created from the mass overfishing that we are doing today, for example, the overfishing of menhaden. These are types of fish which were vastly abundant years ago, and due to the demand for chicken feed and fish oil, to create products such as Omega-3 pills, there has been a dramatic decline in populations. These have knock on effects as they are the base of the food chain for bluefish and striped bass, meaning that those populations have also declined. Mission Blue has around 121 hope spots around the world and hopefully that number will continue to grow, saving more and more marine life.

images from nature.org,wantedonline.co.za

"We have become frighteningly effective at altering nature"

-Sylvia Earle

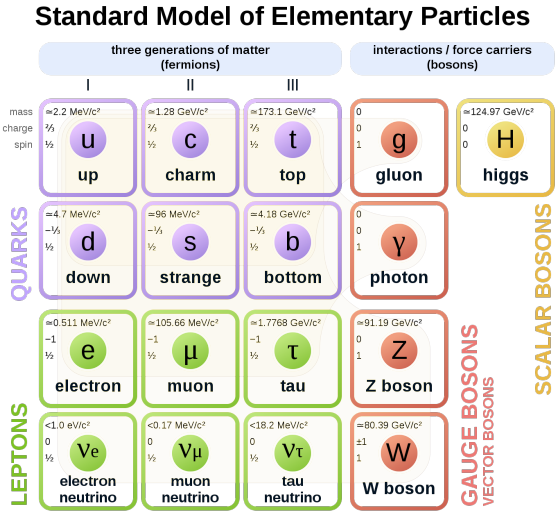
Bosons: a brief introduction to the evolution of particle physics

By Lucy Grunnell

Bosons are the force-carrying particles associated with all particle reactions. Also referred to as exchange particles, they allow particles to react with each other through a fundamental force. There are multiple different types of bosons: weak bosons allow beta +- decay to occur, a more commonplace reaction. Then there's the Higgs Boson, a famous yet ambiguous boson which was first discovered only 9 years ago. The Higgs Boson is not a gauge boson like weak bosons but a scalar boson, so it does not carry force. The particle interactions that I'm discussing are between quarks, the minuscule particles that group together to form protons and neutrons (sound familiar?). Given that they're so tiny, you may ask why they're so important. Well, hypothetically, if gauge bosons didn't exist then there would be nothing allowing a force from acting on interacting quarks. Therefore, these particles cannot react. Considering the world has revolved around continuous reactions since the Big Bang, it would be a catastrophe. With no gauge bosons, no atoms would exist and so the whole universe as we know it would be void of anything but a pool of quarks and leptons, nothing else.

As bosons have the minute size of <1x10^-16 m and the so-called "interesting particle collisions" that we would like to observe are incredibly rare, investigating these particles is no easy task. To maximise the number of particle interactions that take place we must have a controlled environment which creates them. This is where the large hadron collider (LHC) comes in. Essentially, the LHC is an underground tunnel with radius 27km which acts as a circular vessel to fire protons at each other at speeds of almost 300 million metres per second. It is the most powerful accelerator in the world. To put that into context, these protons are travelling fast enough to travel around the circumference of the earth 7.5 times a second! However, to actually study the products from these reactions we need yet another device as they obviously aren't visible to the naked eye. Even if they were, the reaction would be over before we could notice anything ever happened. Hence we use a detector rigged up to a computer to churn through mammoth amounts of data for us.

I've hardly scratched the surface on particle physics but just enough for the purpose of this article··· The investigation of these tiny particles (quarks) and the particles that allow these tiny particles to react with a force (bosons) became more prominent from 1930, when they started to accumulate some information on the fundamental structure of matter. The idea of quantum physics was introduced by Max Planck and Albert Einstein as early as the beginning of the 20th century. Einstein's 1905 paper discussed the particle nature of light, which wasn't recognised as the photon until 1926. These were the first building blocks which permitted further investigation into the quantum world. Fast forward a few decades to e early 1970s,



the standard model of physics was constructed to demonstrate our best understanding of fundamental particles and forces.

Note my previous use of the word 'best' understanding for the standard model. We have a certain understanding of the world but there is so much more that we haven't discovered yet. While this model has proven itself through explaining experiments and well-tested theory it is still very much nebulous. It can be used to accurately predict phenomena yet doesn't account for 25% of matter: dark matter. It accounts for three of the four fundamental forces (the weak force, strong force and electromagnetism) yet gravity isn't featured. As for dark matter, its vagueness is in its name. This mysterious category of matter doesn't interact with light which creates numerous problems in itself.

So what is the future for particle physics in general? Well, as it remains so mysterious physicists are currently looking to shed some light on the matter (excuse the dark matter pun). Although yet again, it's not that simple. Theorists are currently investigating the "implausible possible". In other words, anything that seems unreasonable but theoretically could happen given that there's no reason for it not to happen. Scientists today are actively questioning and researching the theory of supersymmetry, where some sort of "shadow world" exists and every particle has a symmetrical "shadow" particle. First physicists proved the Higgs field, an invisible energy field which gives mass to quarks, explaining how they can interact. More recently, scientists think they have indeed found a deviation from the standard model due to a behaviour of the beauty quark, a non-naturally occurring quark which is produced in the large hadron collider. A possible explanation of this strange reaction could be the leptoquark- an undiscovered particle (for now!) which can theoretically make it easier to produce electrons during decay. However, this is just a hypothesis.

Evidently, our understanding of the particle world is, in the grand scheme of things, pretty limited. Although, all of the unknown facts is what makes it so exciting. As we strive to build on our knowledge and discover new phenomena, gradual discovery is what contributes to our progress. So what will be the next big discovery in quantum physics? More force-carrying particles? A parallel particle world? Who knows…

The gut: the most underrated organ?

By Zoë Bristow

The large intestine is responsible for the last step of digestion: removing excess water and salts out from undigested material, and excreting the faeces that form. But is that really everything it's responsible for?

The large intestine is often forgotten in research, perhaps because it is deemed the most embarrassing organ, yet it is responsible for 95% of all serotonin production in the whole body, amongst 20 other vital hormones. Serotonin is the hormone famous for stabilising mood and managing well-being. To make serotonin, the body needs a protein called tryptophan, an essential amino acid which the body can't produce and therefore must be present in our diet. Luckily, it is found in lots of very common foods, such as milk, oats, nuts and seeds, chocolate and bananas, and most people have more than enough in their usual diets. Cells that can produce serotonin contain the enzyme tryptophan hydroxylase, which hydroxylates tryptophan to form 5-hydroxytryptamine, also known as serotonin.

Serotonin also regulates peristalsis, the wave like contraction of muscles which pushes the undigested material through the gut. Additionally, it is responsible for feelings of nausea and pain within the gut, which explains why it is produced there. Interestingly, this is the first clear crossover between mental and physical health within the large intestine, as the same hormone, which is produced and received in the same places, seems to regulate both. It has already been shown that 90% of all communications between the gut and the brain move in the direction of gut to brain. This essentially means that a "gut feeling" is completely real, and often your gut understands your mood before your brain does.

We often hear about the gut micro-biome, where between 300 and 500 different bacterial species exist, on the most part, in a mutual, symbiotic relationship with humans. These bacteria are responsible for many different functions, for example the production of short chain fatty acids (the main source of nutrition for the cells in the large intestine), the creation of vitamin K (responsible for ensuring the clotting properties of blood) and folic acid (promotes the production of healthy red blood cells), and even play a large role in keeping our immune systems healthy. The gut is closely intertwined with around 2/3 of the lymphatic system, responsible for the production and release of cytokines (which stimulate an immune response in the event of an infection), so it is not a surprise that the bacteria play a role in this process. The micro-biome also defends itself from invading pathogens very effectively.

Scientists are only just beginning to discover how sensitive this micro-biome is towards emotions. A study published in the Journal of Paediatric Gastroenterology and Nutrition in 2019, looked at the links between stress and induced changes in the micro-biome of mice. They exposed some mice to some social disruption stress and others they left alone as a control. Then they measured the level of short chain fatty acids inside of the colon, as a measure for whether or not the micro-biome responded to stress and found that the mice who experienced stress had significantly lower levels of short chain fatty acids in their gut. This change in the micro-biome actually decreases the colons capacity to carry out regular processes, such as fighting off pathogens, and therefore can lead to infection-caused diseases, such as irritable bowel disease (IBS), or types of inflammatory bowel diseases, such as ulcers.

These unfortunate side effects are a product of evolution. During the stress response (also known as fight or flight), the body has evolved to stop all non-essential processes, including digestion, in order to conserve energy for more important actions. This is the reason why so many people experience nervous vomiting or diarrhoea. Even just the sensation of "butterflies" is in fact the large intestine stopping its normal processes, and even changing the bacterial micro-biome, in order to conserve energy.

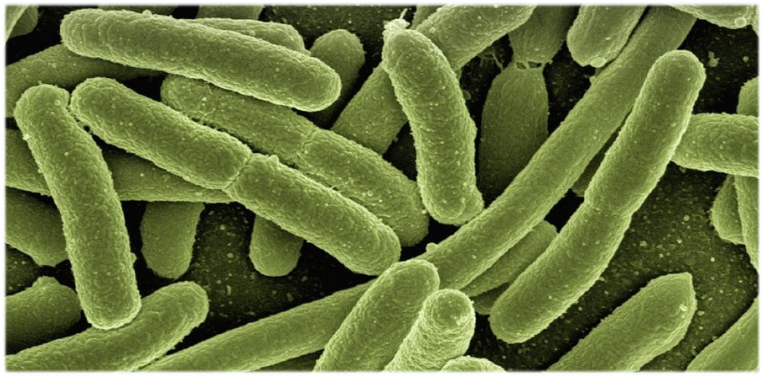
An interesting treatment for chronic stress and anxiety disorders which is emerging from these discoveries is the use of probiotics and antibiotics, potentially tailored exactly to an individual's micro-biome's needs, in order to combat some of the symptoms. It is incredibly simplified from many of the medicinal treatments available at the moment, and has already been proven to help improve the quality of life for some IBS sufferers.

Evidently, the gut is a wonderful organ and there is so much more information to be found out about it. If you found this interesting and would like to read more here are some interesting links you might like to go and have a look at:

https://www.ted.com/talks/giulia_enders_the_surprisingly_charming_science_of_your_gut

https://www.ted.com/talks/henna_maria_uusitupa_how_the_gut_microbes_you_re_born_with_affect_your_lifelong_health?language=en

https://m.youtube.com/watch?v=qlHIWXWDuF0&feature=youtu.be



Bacterial microbiome in the gut

How Carbon-14 is used to track fossil fuel emissions

By Ghazal Ershadi-Oskoui

Carbon-14 is the radioactive isotope of carbon. It is made in the atmosphere by high-energy cosmic rays (these are “high-energy protons and atomic nuclei that move through space at nearly the speed of light”) from space. This happens when the atoms of gases in the upper layers of the atmosphere are hit by these high-energy cosmic rays, causing their nuclei to break apart and fly off at a high speed. Nuclear transformations can take place as a result of the nuclei hitting other atoms, resulting in elements in the air changing into different isotopes. Carbon-14 is formed when atoms of nitrogen gas (which makes up nearly 80% of our atmosphere) collide with a very fast-moving neutron. Due to isotopes of the same element having the same chemical properties, carbon-14 atoms are able to react with oxygen in the atmosphere to produce carbon dioxide (just like the common and stable isotope, carbon-12). It is then absorbed by plants in the process of photosynthesis therefore carbon-14 can enter the food chain.

By burning fossil fuels, carbon dioxide (a greenhouse gas) is released into the atmosphere. Over the years, we have witnessed carbon dioxide emissions deteriorate the health of our own as well as the planet’s. For example, they cause global warming by trapping heat, whilst also contributing to respiratory diseases from air pollution. Extreme weather is also a result of climate change along with food supply disruptions, and increased wildfires. The harm caused as a result of high carbon emissions (which mainly comes from burning fossil fuels) are endless and anything that can be done to prevent carbon emissions increase would count as progress.

In June last year (2020), it was discovered that carbon-14 can be used to track the emissions of fossil fuels. Carbon-14 is an ideal tracer for carbon dioxide formed from the combustion of fossil fuels, as scientists can use the measurements to determine how much CO2 made from the C-14 isotope has been mixed with carbon dioxide samples that are made without C-14. From this, the proportion of the carbon dioxide in the air samples which come from fossil fuel emissions can be determined. As a result, the first ever estimate of carbon dioxide produced by fossil fuel emissions has been calculated. The carbon in fossil fuel does not have C-14 at all, because it has a half-life of about 5,700 years (which is considered to be short). Therefore, it was clear where the carbon emissions came from (whether it be natural or combustion from industry or vehicles).

Co-author and UCL Associate Professor Eloise Marais (UCL Geography) said: “Burning fossil fuels produces fine particles laden with toxins that are small enough to penetrate deep into the lungs. The risks of inhaling these particles are well documented”. An estimated 1 in 5 deaths every year have been discovered to be linked to fossil fuel pollution. The research, led by Harvard University in collaboration with UCL, the University of Birmingham and the University of Leicester, has been published in the journal Environmental Research. The study shows that more than 8 million people around the globe die each year as a result of breathing in air containing particles from burning fuels like coal, petrol and diesel, which aggravate respiratory conditions like asthma and can lead to lung cancer, coronary heart disease, strokes and early death. By being able to track fossil fuel emissions (using C-14), there is the possibility of being able to reduce the emissions and therefore reduce the number of deaths caused by them.

Scientists at Harvard University also developed a new risk assessment model that linked the concentration levels of particulates from fossil fuel emissions to health outcomes. This new model found a higher mortality rate for long-term exposure to fossil fuel emissions, including at lower concentrations. The researchers found that, globally, exposure to particulate matter from fossil fuel emissions accounted for 21.5 percent of total deaths in 2012, falling to 18% in 2018 due to tightening air quality measures in China.

Combustion of fossil fuels to generate electricity contributes to large amount of the emissions. In US, coal only accounted for 31% of energy generated in 2017, but it was responsible for 68% of the total emissions. Renewable energy sources of solar, hydroelectric and wind only accounted for 16% of energy generation. The remainder was generated by nuclear power, natural gas and petroleum. However, there would be a rapid change as in according to a recent estimate, the share of electricity generated by renewable sources could be doubled from 19% in 2019 to 38% in 2050.

Much of the debate on climate change focuses on greenhouse gases, in particular CO2. Hopefully, these findings put a greater sense of urgency in policy makers and others to switch to alternative energy sources and prevent many more millions of needless deaths every year. The ability to understand the precise impact that burning fossil fuels has on climate change can help us to try and reduce these emissions as much as possible. It gives us hope for a future in which we do not rely upon fossil fuels as much as we do now.

The development of the Covid-19 vaccine:

By Priya Lochab

Around this time last year, a novel coronavirus was only just emerging in the UK. The virus was first established in Wuhan, China in late 2019. The first ever hospitalisation was on the 16th of December. In early 2020, the Wuhan Health Commission then released a statement about early signs of what looked like a pneumonia outbreak in the city. The message conveyed the imminent danger of the virus and on the 11th of January the first death from corona virus was recorded. Since then, the corona virus has developed into a global pandemic and taken over two million lives. Through this tragedy, scientists all over the world have come together to produce several safe and effective vaccines, all in under a year.

Many knew that this virus had 'pandemic potential'. This virus had no reliable diagnostic test and was prevalent in a big Chinese city during the winter months near the Chinese New Year. Very quickly, scientists became concerned about the virus. On the 11th of January 2020, the genetic sequence of the corona virus vaccine was published. Immunologists began putting this tiny piece of information in their platform vaccine technology and from this point immunologists have been working to produce a vaccine. By Monday morning on the 13th of January the vaccine had been designed. Scientists were able to move quickly as they had a template used to design different type of vaccines for diseases like malaria, flu and, crucially, a different type of coronavirus, MERS.

At this point many international pharmaceutical companies began to get involved in the vaccine production. Companies such as Johnson and Johnson, GlaxoKlineSmith and AstraZeneca were among the first. This accelerated the progression of the vaccine as tens of billions of dollars were poured into the system.

By April, the UK was well into its first lockdown and the only real exit strategy was a vaccine. Immunologists now had to test the vaccine on humans, meaning they needed volunteers. After opening the page where members of the public could sign up, over 10,000 volunteered within the first few hours. Following the support from one of these corporations, the trials began.

The trialling progress was spilt in two stages with first beginning in April 2020. In Phase 1 the scientists gathered volunteers and blind testing occurred. This is a process in which volunteers are given one of two vaccines: the corona virus vaccine or a placebo. In this way they could measure the safety of the vaccine, analysing its possible adverse effects.

After this stage had been fulfilled Phase 2 began. This was concerned with evaluating the efficacy of the vaccine, completed through several clinical trials observed by the WHO. Scientists could then see how effective the design for the vaccine was and edit it.

Finally, the authorisation of the vaccines in the UK occurred in December 2020. The UK was the first country to give a corona virus jab in the world and on the 8th of December the UK watched Margaret Keenan take the first injection of the vaccine. The Pfizer vaccine was the first to be rolled out, followed by the Oxford AstraZeneca Vaccine, which were both approved by the UK regulator (MHRA).

Currently, there are three approved vaccines in the UK, the Pfizer/ BioNTech (in use since 8 December), the Oxford/AstraZeneca (in use since 4 January) and the Moderna (this vaccine has been approved, but doses will not be available in the UK until spring). These vaccines will save millions of lives and it is all due to the amazing scientists and immunologist who worked ridiculous hours to allow us to be in the position we are now. The UK is a leading country in the vaccine roll-out with over 17 million people having received their first jab. We are now able to say that we are slowly moving out of this pandemic towards the new normal and we have the scientists and immunologists to thank for it.

Margaret Keenan receives the Pfizer vaccination (08/10/20)

Can we kill cancer cells using strains of bacteria? Is this the new face of treatment?

By Fatimah Mazen

It is common knowledge that our bodies fight off foreign entities through our immunity and that our regular cells have mechanisms that prevent immune cells from attacking them. However, with developing research it has become known that malignant foreign cells can project these mechanisms and therefore our immune system is not able to recognise the cancerous tissue as a foreign body.

This is a substantial issue with cancer patients, but in past research, a form of treatment called immunotherapy has allowed our bodies to get rid of that signal. Whilst the theory of immunotherapy sounds prosperous and optimistic for cancer patients it is only successful for a limited number of cancers. It may restore the immune system, but it can also overpower it.

New studies researched by Yves Chabu at the Division of Biological Sciences have discovered something quite promising! He claims that despite the similarities that cancers have, every tissue has its individuality and differences therefore not all therapies will contribute to helping fight it off.

Nonetheless, Yves Chabu has discovered 50-year-old bacteria that may help all cancers of all variations. The bacteria is described as “genetically pliable”, essentially meaning genetically ‘flexible’ so it is able to be genetically modified in hopes that it is patient specific or more so cancer specific. This new discovery is as perplexing as it sounds, we can modify a bacterium so that when it enters the body it can identify the cancer’s weakness and kill it without causing major side effects. This form of treatment is expected to be used when no therapies are successful for a patient.

This idea of genetically modifying pathogens to treat cancers is more common than you may think. There have been studies where a non-toxic form of salmonella was modified to kill cancer cells for a specific patient. Yves Chabu has used this ideology to present his case, which is so far successful, and could be the next major advance in cancer research!

Cancer prevention or cancer treatment?

By Tatiana Lumb

As the medical world has progressed, scientists have gained a better understanding for how diseases work, and therefore how to cure them. One of the most well-known diseases is cancer, affecting 1 in 2 people at some point in their lifetime. This makes it the leading cause of death worldwide. And up until now, researchers have spent billions of dollars investing in cancer treatments and trying to find a 'cure' for cancer. Although different methods can help kill cancer, such as chemotherapy, radiation and surgery, is that really what we should be investing in, or should we focus more on trying to prevent cancer in the first place?

As scientists have gained a greater understanding for how cancer works, they have realised that more than a third of cancers are preventable and can be prevented by cutting out risk factors. Some risk factors include tobacco use, alcohol use, lack of sun protection, unhealthy diet and physical inactivity. For example, lung cancer kills more people than any other cancer - a trend that is expected to continue unless efforts for global tobacco control are greatly intensified.

As well as cutting out risk factors, the global burden of specific types of cancers can be reduced by vaccination and screening programmes. There are safe and effective vaccines against the human papilloma virus which causes cervical cancer and against the hepatitis B virus that causes liver cancer. Cervical cancer is the second most common cancer in women worldwide. Cost-effective and accessible screening programmes to detect cervical cancer or pre-cancer combined with prompt treatment can reduce deaths in women. Liver cancer killed more than 700000 people in 2008, and 78% of liver cancers are caused by the hepatitis B virus and the hepatitis C virus. The HBV vaccine can prevent most of the new HBV infections.

Thirdly, many cancers have a high chance of cure if detected early and treated adequately. Some of the most common cancer types, such as skin cancer, breast cancer, cervical cancer, oral cancer and colorectal cancer are largely curable if they are detected early and treated appropriately. Early detection can be increased if governments invest in awareness schemes. Successful awareness schemes already exist in some places, such as in Australia where there is a skin cancer awareness program, which has helped slow the increase in skin cancer cases greatly.

Finally, as much as new treatments for cancer could save many lives, many of these new treatments are only available to people in high income countries that can afford these treatments and the equipment needed in the hospitals. Around 70% of the cancer deaths occur in low or middle-income countries. Although at first, cancer prevention programs will be costly, but over long periods of time they could be extremely effective and could reduce the financial burden cancer cause to many families in low-income countries.

Women In Science:

By Keri Hammond

Women throughout history have accounted for 7% of significant scientific discoveries. When looking through all the early pioneering mathematicians from India, Greece, and Rome, it was lists of men. One of the first female mathematicians I discovered was Hypatia: an astronomer and mathematician between 360AD-415AD.

Fast-forward over 1000 years to a few more prominent female scientists: Maria Winkelmann (1670-1720) who was a pioneer in German astronomy. She was the first woman to find a new comet, but her work was published by her husband in his name. Mary Anning (1799-1847) was a key figure in fossil discoveries and palaeontology. She was the initial person to discover an ichthyosaur skeleton; however, she was not allowed to join the Geological Society and wasn't acknowledged for her discoveries. Finally, Marie Curie (1867-1934), who was responsible for the identification of radium during her work on radioactivity. Unlike the other women I have mentioned, she did receive some credit for her discovery and was awarded a Nobel Prize for Physics in 1903, and a Nobel prize for Chemistry in 1911.

Arguably the most famous female scientist, her works are still less known than her male counterparts. She gets much less credit than scientists like Einstein who were from a similar period.

At the turn of the 20th Century, more and more women were becoming prominent in the science field. Since 1900, roughly 20% of scientific discoveries have been made by women.

A few of the brilliant female scientists from the 20th Century I found were:

- Rosalind Franklin (1920-1958): She was partially responsible for the discovery that DNA is a double-stranded helix structure.
- Alice Ball (1892-1916): The first African-American woman to earn a Master's from the University of Hawaii. She discovered a treatment for leprosy which was then used until the 1940s. Another victim of stolen work, until a supervisor, discredited the claimant of her discovery.
- Dorothy Hodgkin (1910-1994): She was the third woman to be awarded the Nobel Prize for Chemistry. She discovered the structure of vitamin B12 and insulin.
- Grace Hopper (1906-1992): A key programmer of the 1944 Harvard Mk1 computer. She also invented the first compiler for a programming language.
- Rachel Carson (1907-1964): One of the first scientists urging against the use of DDT in agriculture because of the risks of bioaccumulation

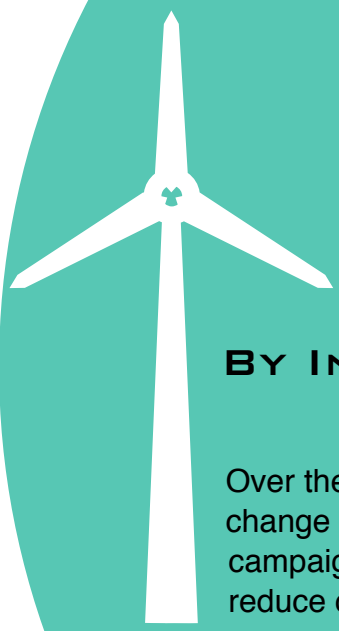
Rachel Carson

Dorothy Hodgkin

Now we are in 2021, how have things changed?

30% of global scientific researchers are women, and in the UK, only 14.4% of the UK STEM workforce are women, accounting for 793,437 people. Despite the number of women applying to STEM university courses rapidly increasing every year, there is still a large gender divide, particularly in computer programming degrees. Additionally, despite 56% of foundation doctors in the UK being female, there is a disparity in further qualifications. Only 32% of surgery trainees are female and over 70% of gynaecology and paediatrics students are female.

I will now present my hopes for the future in science so that more progress can be made. With incentives, we are seeing the engineering and IT gender gap slowly diminishing. To solve this issue, I believe that additional funding and encouragement needs to be applied in schools. A key reason why fewer female scientists are in the industry is that girls are not supported to take science A-levels. Luckily for us, Putney High is particularly strong in this field. The UK economy has a growing quaternary (research) sector; therefore, encouraging less of a gender divide is essential if we want to make progress



The role of renewable energies in our progress towards becoming a carbon neutral country:

By Ines Farah

Over the last decade there has been great progress in increasing awareness about climate change due to the introduction of this theme in education systems, environmental campaigns, and greater talk of global warming in the news. Everyone knows that we need to reduce our carbon emissions to stop the worsening effects of climate change. The problem is, most people believe that cutting all our uses of fossil fuels and solely relying on renewable sources of energy are the way to be completely carbon neutral which, in theory, should be true. However, there are many limitations to completely relying on renewable energies, the main one being that they are unreliable. Who knows if the wind levels will always be high? What if we go through a particularly cloudy month, decreasing the access to the Sun? Although renewable energy sources will increasingly contribute to the world's energy source and supply in the future, we must explore different ways of becoming carbon neutral.

Renewable energies are the only sources which can guarantee the security of future energy supplies seeing as the main sources such as wind and the sun are infinite. Our Sun, for instance is the most abundant form of energy available on our planet. Renewables create negligible environmental damage when compared to fossil fuels. The burning of fossil fuels creates harmful greenhouse gas emissions that cause global warming and climate change and it also leads to all sorts of environmental pollution. Indirectly, our dependence on fossil fuels also leads to the extinction of many species and massive biodiversity loss.

Furthermore, the old excuse that renewable energy is too expensive is just that: an excuse. These days, the energy produced by renewables is just as affordable as energy produced by fossil fuels, if not cheaper in some cases and is projected to be priced even lower over time.

Let's focus on wind power to see how wind turbines work and how many would be needed to make a significant impact. A wind turbine is an electricity generator which converts kinetic energy from the wind into electricity. A typical modern wind turbine on a suitable site can generate about 2 Megawatts (MW) of electrical power. To put it into context, 2 MW can then be used to toast 178,000 pieces of toast or power an average home for a bit longer than a month.

-We know that the equation to find Kinetic Energy = ½ x (mass) x (velocity)^2

-With some rearranging, and using the area of the wind turbine's blades when they rotate, as well as the density of air, we get: **Kinetic Energy = ½ x (density) x (velocity)^3 x (Area)**

-For a wind turbine with blades of Length 20m, Area 1300 m^2, Density 1.2 kg m^-3 and Velocity 15 ms^-1, the Kinetic Energy = ½ x (1.2) x (15)^3 x 1300 = 2.6 MW

-The calculation above shows that the maximum power output of a large wind turbine at a windy site could be more than about 2 MW. To generate the same power as a 5,000 MW power station, about 2,500 wind turbines would need to be constructed and connected to the electricity network.

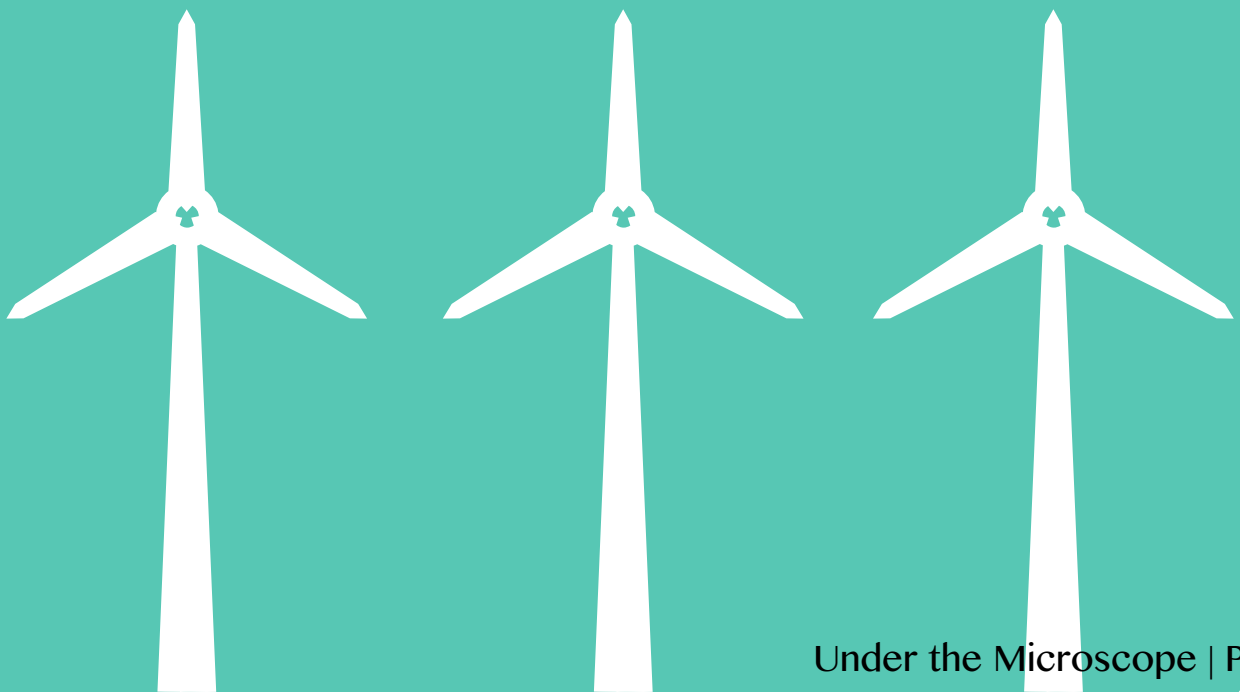
The working above shows that thousands of wind turbines would be needed to make a significant contribution to UK energy needs. In fact, an estimate was made for how many wind turbines would be needed to supply the entire world's electricity consumption. This turned out to be 1.49 million efficient wind turbines, most of which would have to be larger ones which produce more electricity. Although this sounds ideal, there is simply not enough space on our Earth to accommodate this number seeing as the conditions would always have to be extremely windy for the wind turbines to produce sufficient electricity.

The challenge with renewable energy is that we still need carbon-based fuel for backing up renewable energy infrastructure and heavy-duty transportation like trains and planes. For an aeroplane to be fully fuelled by solar energy there would have to be around 12,000 solar panels on the wings (or more for larger aircrafts!) and even that wouldn't guarantee the plane staying airborne for the entire journey!

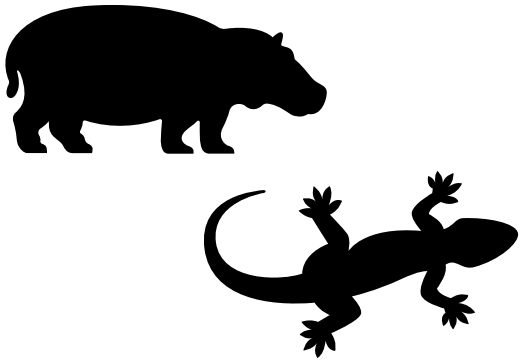
While renewable energy sources are important for reducing future emissions, energy leaders and experts have not yet figured out how to significantly reduce emissions within our existing carbon-based energy system. Until they do, making it cheaper for businesses to invest in Carbon Capture and Storage is a good option to immediately reduce fossil fuel emissions. Carbon Capture and Storage (CCS) is a technological innovation that allows carbon dioxide to be captured and stored instead of allowing it to accumulate in the atmosphere. CCS will potentially allow us to keep burning oil and gas without the emissions being a problem seeing as they would be stored. It is also very effective with up to 90% of all emissions being captured. However, it also gives industries and governments an excuse to do very little to address climate change, making it an easy way out of cutting our carbon emissions as well as being a very expensive procedure.

The reality is that oil and gas companies gain too much to simply stop their production of energy. They have traditionally been profitable for investors and energy suppliers as well as provided inexpensive electricity for consumers. However, the Paris Agreement of 2015 has stimulated institutions such as the finance sector to decisively shift in favour of clean energy. This means that more banks will invest in renewable energies, gradually decreasing the number of investors in coal, oil, or gas companies. Unfortunately, it isn't quite as simple as that and there are more factors involved but it is still a good start and will help increase global awareness of fossil fuels.

In conclusion, renewable energies are a great way to reduce our carbon emissions to try to meet our Net Zero carbon goal in accordance with the Paris Agreement. They are a good way of guiding our energy economy to a cleaner future as well as create new jobs ensuring that several opportunities are made at once



HOW PREDICTABLE IS EVOLUTION?



BY POPPY CRAIG-MCFEELY

Evolution can be defined as the change in the heritable characteristics of a biological population over successive generations. So, is evolution merely a random series of events or does it follow predictable patterns? This is contingency versus determinism. A greater influence of determinism would mean that outcomes are more repeatable and less subject to variations, whilst contingency suggests that outcomes are reliant on random events, making them less repeatable.

At first glance, the hypothesis of evolutionary predictability appears difficult to support because the mutations which cause evolutionary innovations are inherently random, and so implicitly unpredictable. Therefore, one might conclude that the evolutionary outcomes must also be random. However, that would be over simplistic, because evolution involves the natural selection of one desirable mutation or trait over another. The extent to which that selective process is more subject to deterministic or contingent forces is the crux of the question posed.

The concept of evolutionary contingency was put forward by the late invertebrate palaeontologist, Stephen Jay Gould (1947-2002), who contended that evolutionary outcomes are the result of random mutations that lead evolution in a completely new direction, making them less repeatable. He maintained that evolution is a historical process and historical processes display some degree of contingency whereby their outcomes are sensitive to specific events which can fundamentally change the future, so it is contingency which makes outcomes unpredictable. In his view, if the tape of life was 'replayed' it would produce very different outcomes.

Alternatively, another palaeontologist, Simon Conway Morris, suggested that evolution is no different from any other historical process, in that it is only dependent upon a series of events until the moment. This is because homoplasy (repeated evolution of similar traits not derived from a common ancestor) is widespread in nature suggesting that evolution is not so unpredictable. Universal physical or chemical laws will determine very similar optimal solutions under the same environmental conditions to overcome the selection pressure, causing different organisms to independently evolve similar traits. Conway Morris contends that this determinism produces convergent evolution which is completely ubiquitous.

Homoplasy can arise from similar selection pressures acting on adapting species. Experiments within nature and in the lab have demonstrated how closely related species tend to evolve similar adaptations to similar selection pressures. Sometimes these occur over the course of only a couple of generations which would indicate that evolution is indeed predictable, and further, that foreseeable evolutionary changes may occur extremely fast. Such cases include different species of anole lizards living in different islands in the Caribbean evolving convergent solutions to become better adapted to their habitats (e.g. similar adaptations for species living in the canopy versus another set of similar features for species living on the ground on different islands).

Perhaps one of the best examples of convergence is the need for sight and the homologous evolution of the eye. Octopods have eyes that appear very similar to those of humans and other vertebrates despite our most recent common ancestral connection subsisting in the oceans over 550 million years ago without the slightest notion of an eye. This indicates an element of determinism and that if the tape of time were rerun, one could predict with some confidence that eye-like structures would evolve again. Another well-known example is the tendency for island animals, e.g. hippos and mammoths, to become smaller than their continental counterparts.

However, in support of the contingent model of evolution, there is evidence that random mutations can be equally successful and lead to less predictable and less repeatable evolutionary outcomes. An example is the environmental challenge of aquatic motion. Fish have evolved to use tails, eels and sea snakes use their whole body for propulsion, whereas penguins and octopods use modified forelimbs to move through water. All these adaptations evolved non-convergently and provide individual but not ubiquitous solutions to a problem posed by the environment. In fact, the world is filled with examples of unique evolutionary trajectories that are unknown in other regions of the planet or in other periods of time. For example, the duck-billed platypus with its slightly comical assemblage of characteristics not to be found outside Australia.

More recently, Richard Lenski's ongoing long term bacterial evolutionary experiment, which began in 1988, has failed to produce exact replicate evolution over 70 000 generations. 12 identical lines of E.coli bacteria were grown in identical conditions and, initially, all grew faster and produced larger cells showing convergent evolution and parallel changes. This demonstrates that closely related species may quickly develop similar solutions to similar environmental pressures given their similar genetic background. However, after around 31,000 generations, one line exhibited an idiosyncratic adaptation of their biochemical machinery: the citrate phenomenon. This small group of bacteria were able to respire aerobically using citrate instead of glucose and so took a very different evolutionary path. Any attempts to encourage the other lines to follow suit have failed, indicating that this anomalous result was not repeatable and hence we can determine that it would not occur in the future. Therefore, historical contingency is especially important when it facilitates the evolution of key innovations that are not easily evolved by gradual, cumulative selection.

So, two very compelling but contradictory arguments regarding the predictability of evolution have arisen. The evidence suggests that both have played large parts in the natural history of our world. Faced with similar selection pressures, similar populations will indeed often produce convergent evolutionary outcomes, but the process is not universal, and life produces many unique evolutionary trajectories e.g. the human lineage.

Convergent evolution, in my opinion, appears to be a larger contributor to the anatomical evolution of organisms. The evolution of different types of traits such as the eye or forearms are therefore more predictable.

However, the evolution of biochemical mechanisms within an organism is more likely to have occurred through a contingent evolutionary scheme. Perhaps the evolution of the first ever organisms occurred contingently through a random arrangement of amino acids with the correct amount of energy. The biochemistry that caused the creation of the first ever eukaryotic cell likely occurred contingently through the mutualistic connection of archaea and bacteria. This is certainly unpredictable and unrepeatable, as evidenced by the lack of life found beyond our planet to date.

In conclusion, at the heart of evolution is the random process of DNA mutations causing genetic variation, but evolution is full of recurring patterns rather than the expected directionless process. Therefore, evolutionary change is often driven by the deterministic force of natural selection, but that natural selection works upon variation that arises unpredictably through time by random mutation. On balance, the evidence indicates that evolution tends to be surprisingly repeatable among closely related lineages, but disparate outcomes become more likely as the footprint of history grows deeper. Consequently, both the theory of convergence and contingency are needed when trying to make predictions about different types of evolution. It seems that the conflict between contingency and predictability is a matter of scale as organisms tend to achieve similar solutions to similar problems but give it enough time (or small enough population sizes as shown by Richard Lenski's experiment), and anything is possible.

Columns

Tatiana Lumb

Poppy Craig-McFeely

An Interview and Unsung Heroes from our columnists, Poppy and Tati

Interview -By Poppy Craig-McFeely

Professor Nigel Raine is a global leader in the fields of animal behaviour, pollination ecology and pollinator conservation. His specialist interest is wild bees and more specifically, their pollinating relationship with flowers, which he researches from the University of Guelph, Canada as the Rebanks Family Chair in Pollinator Conservation.

He kindly agreed to be interviewed by our Columnists, Poppy Craig-McFeely and Tatiana Lumb, and we would like to thank Professor N. Raine for his generosity and eagerness to answer our questions.

Why bees?

That is a very good question because the importance of pollinators is not widely recognised with very few people making the connection between pollinators and the food on their plate! In fact, probably 1/3 mouthfuls of food we eat depend on the pollination service of insects, including most fruits, vegetables and nuts. Also 90% of flowering plant species worldwide rely on animal vectored pollination, making pollinators (particularly wild bees) an essential part of the natural ecosystem. But there are concerns over global pollinator declines which has highlighted a need to address pollinator conservation to ensure sustainable agriculture, especially as world demand for both quantity and diversity of food increases. In fact, economic values of pollination services to global agriculture are currently estimated at US$235 – 577 billion. Hearing that there are over 20,000 species of bee worldwide generally makes people's heads spin, surprised that they are more than just honeybees. In essence, bees are essential creatures that we cannot afford to lose.

What do you do day to day?

I lead a research team which studies the behaviour and ecology of pollinators, and in particular the impacts of environmental stressors e.g. how pesticide exposure, which is used to boost crop quality and yield, affects pollinator health. In recent years, the use of neonicotinoid pesticides has increased and unlike contact pesticides, which remain on the surface of the treated foliage, this class of systemic pesticides are taken up by the plant. Neonicotinoids are then transported to all of the plant's tissues, including the pollen and nectar, and remains active for many weeks for season long pest protection. Unfortunately, neonicotinoids also bind to receptors in the nervous system of insects and in fatal doses may cause paralysis and death.

Bees have a particular genetic vulnerability to neonicotinoids because they have more of these receptors than other insects, as well as more learning and memory genes for their highly evolved system of social communication and organisation. Also, unlike many insect pest species which are able to detoxify harmful chemicals, bees possess fewer genes for detoxification.

Our research has shown that neonicotinoids act on bees by disrupting the normal flow of information through the nervous system so, even if not fatal, it can affect their foraging behaviour, homing ability and reproductive success.

Using radio frequency identification (RFID) tagging technology to track the behaviour of over 1000 bees, we have shown that the foraging performance of pesticide exposed bees was significantly reduced. This had important knock-on effects for forager recruitment, worker losses and overall worker productivity. Understanding the wider importance of sublethal effects from pesticide exposure is the first step towards balancing the benefits of using agrochemicals in food production against the risk of harming these beneficial animals.

In particular, apples are a crop of global economic importance, but bumblebee colonies which have been exposed to neonicotinoids provided lower visitation rates to apple trees and collected pollen less often. Most importantly, these pesticide- exposed colonies produced apples containing fewer seeds, demonstrating a reduced delivery of pollination services.These findings show that pesticide exposure can impair the ability of bees to provide pollination services, with important implications for both the sustained delivery of stable crop yields and the functioning of natural ecosystems.

We also study the cognitive abilities of bees to adapt to their environment. Bees face complex cognitive tasks daily when making foraging decisions about which flowers to visit in nature’ s dynamic pollination market. Research has shown that foraging bees use a variety of cues, including floral colour, pattern and scent, to recognise, discriminate and learn the flowers from which they collect food. As bees naturally forage in an environment in which the most rewarding flower type often changes, it seems likely that bees which learn quickly have the flexibility to keep track of the most rewarding flowers. Bees also need to learn the locations of their nest, flower patches they visit, and major landmarks in their environment. Therefore, they must continually update the routes they follow as the flowers in bloom change over time. We are able to investigate the adaptive significance of behavioural traits by comparing trait variation under controlled conditions in the lab with the variation in task performance shown by the same bee colonies under field conditions again using RFID. This comparison enables us to observe how behaviour changes with experience, which is fascinating.

And the last aspect of my job is to study the complex evolutionary ecology of plant- pollinator interactions, specifically how pollination systems have evolved to reduce the incidence of 'unproductive' pollen flow between species.

What do you like most about your job?

Being able to investigate the answers to research questions that captivate me, and the chance to translate results from these scientific investigations to a range of audiences, including academic colleagues, policy makers and regulators, farmers, students and the wider public. When people discover my research interests, they are usually intrigued and ask, as you both have done, some variant of the question: "what's going on with the bees?". It's really great to share knowledge about some of the behavioural and ecological adaptions that bees have to deal with within the wide range of challenges they face. However, it is important not to focus on the negatives and I hope that, by communicating my work on how these tiny-brained insects can perform amazing behavioural feats like finding the shortest routes between locations, detecting minute changes in floral electrostatic charge or recognising human faces, I can capture public interest and imagination.

What progress are you looking to make in the future?

The job is not complete by just producing the data. We then have to engage the relevant stakeholder groups and communicate and translate research results in a useful and understandable way to the most appropriate audiences. I really value the time and opportunity to discuss the wider issues and what changes individuals, companies, groups and governments can make to mitigate pollinator declines. Hopefully, by continuing to speak to important individuals such as yourselves, I can continue to increase awareness of how everyday choices have the potential to massively impact biodiversity.

Image of Nigel Raine via University of Guelph

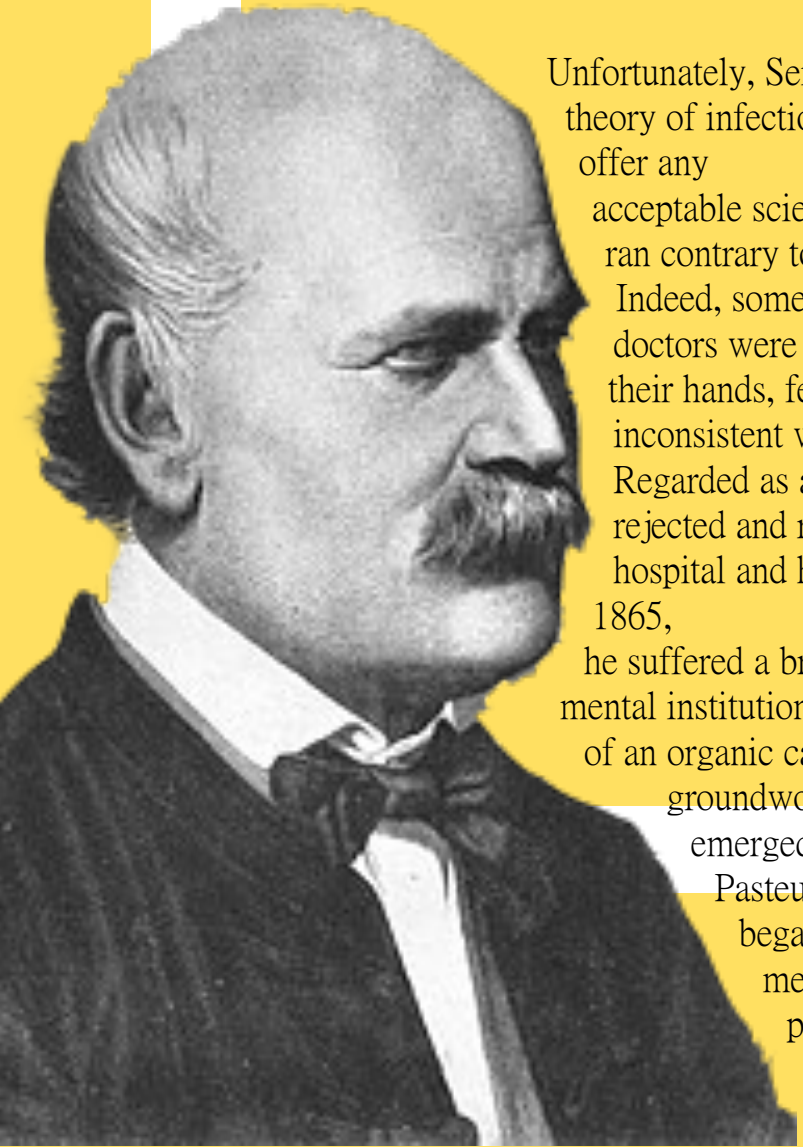
Unsung Heroes

Ignaz Semmelweis -By Poppy Craig-McFeely

During this current COVID-19 pandemic, we are constantly reminded of the importance of hand washing to reduce the spread of infection. The name Louis Pasteur (1822-1895), a French chemist and microbiologist is world famous due to his work which proved germs cause disease. However, few would recognise the name Ignaz Semmelweis (1818-1865), a Hungarian physician and scientist, now posthumously credited as an early pioneer of antiseptic procedures.

Importantly, whilst working on the obstetric ward in Vienna General Hospital (1846-1849), Semmelweis identified an infectious mode of transmission of puerperal sepsis ('childbed fever'), a cause of maternal death following childbirth. At that time, postpartum death was rampant in European and North American hospitals; sometimes reaching a mortality rate of 40% of admitted patients.

In a key observation, Semmelweis developed a theory that puerperal fever was being caused by doctors because doctor' s wards had three times the mortality of midwives' wards. He theorised that decaying matter was remaining on doctors' hands after post-mortems and being brought into contact with the genitals of birth giving women during medical examinations. To combat the spread of puerperal fever, he proposed a radical hand washing theory using chlorinated lime, now a known disinfectant. Described as the 'saviour of mothers' , this simple hand washing practice reduced mortality to below 1%.



Unfortunately, Semmelweis was ahead of his time and the germ theory of infection had not yet been developed. He was unable to offer any acceptable scientific explanation for his findings and his ideas ran contrary to established medical beliefs and practices. Indeed, some doctors were offended at the suggestion that they should wash their hands, feeling that their social status as gentlemen was inconsistent with the idea that their hands could be unclean. Regarded as a controversial figure, Semmelweis' ideas were rejected and ridiculed, his contract was not renewed at the hospital and he was shunned by the medical community. In 1865, he suffered a breakdown and very sadly died as an outcast in a mental institution. Nevertheless, this unsung hero' s speculations of an organic causative agent in puerperal sepsis helped lay the groundwork for the germ theory of infection which emerged several decades later. It was only when Louis Pasteur confirmed the germ theory and Joseph Lister began practising and operating using hygienic methods that the significance of Semmelweis' pioneering work was accepted.

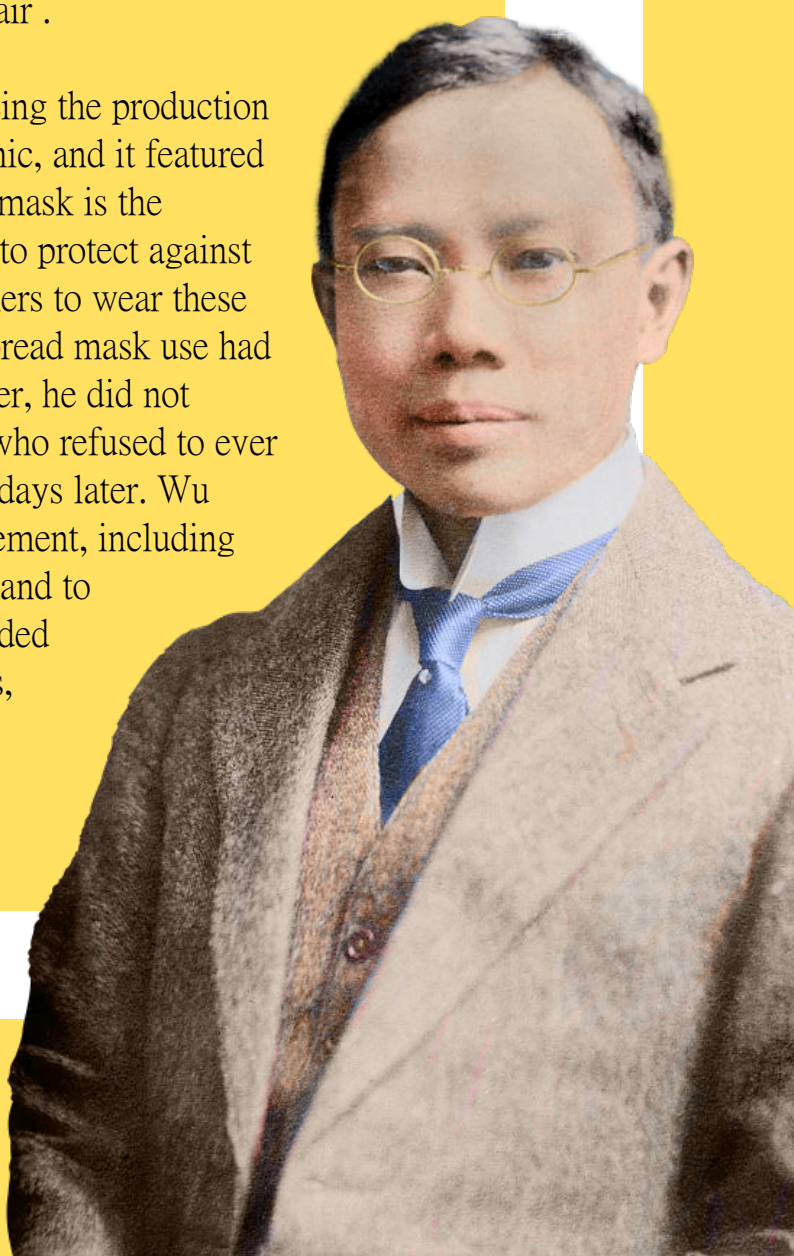
Wu Lien-Teh -By Tati Lumb

Over the past year, we have all gotten used to wearing surgical masks everyday to help protect against the spread of COVID-19. It has also been customary for surgeons to wear masks during procedures to help prevent infections. But who created the first surgical mask?

Dr Wu Lien-teh, a Malayan physician, was celebrated for his work in public health. In 1896, he studied at the University of Cambridge, where he was the first medical student of Chinese descent to ever attend. He then went on to become the first Malayan to be nominated for the Nobel prize in Medicine, in 1935. His undergraduate clinical years were spent at St Mary' s Hospital, London and he then continued his studies at various other schools and institutes.

It all started in the winter of 1910, when Wu was given instructions from the Foreign Office of the Imperial Qing court in Peking, to travel to Harbin to investigate an emerging disease that killed 99.9% of its victims. This is now known as the pneumonic plague, which killed over 60,000 people. Whilst carrying out research there, Wu was able to conduct a postmortem (which was usually not accepted in China at the time) on someone who had died of the plague. This allowed him to realise that the plague was spreading by air, and so Wu developed the now commonly used surgical mask. Similar masks had been seen in the west, however he made them more substantial by adding layers of gauze and cotton to filter the air .

The mask was widely produced, with Wu overseeing the production and distribution of 60,000 masks in a later epidemic, and it featured in many press images. It is believed that the N95 mask is the descendant of Wu's design, which many now use to protect against COVID-19 . He encouraged medical staff and others to wear these masks to protect themselves, the first time widespread mask use had been part of an epidemic control strategy. However, he did not persuade everyone, including a french colleague who refused to ever wear a mask, however he died of the plague four days later. Wu advised authorities to impose restrictions on movement, including stopping trains, to limit the spread of the disease, and to instruct sick people to self-isolate. He also persuaded officials to authorise the cremation of dead bodies, which wasn' t normally accepted in China.



Wu chaired an international conference on the plague that year, helping disseminate knowledge about how to respond to outbreaks. The epidemic helped convince China' s leaders of the need for a modern public health service, and Wu helped establish it in numerous roles before returning to Malaya in 1937.

Book Reviews

"The Beautiful Cure" by Daniel M Davis -Zoe
This book explores the discovery of the immune system, walking through how each part was found, the impact they had on the world of STEM and the scientists behind the discovery. It reads like a story book into which you can get very immersed, and I would highly recommend for anyone interested in biology or medicine.

"Complications" by Atul Gawande -Maya
A great book if you're looking for a medical book that is light but gripping. It explores topics of man vs machine, deadly errors and much more. Between case studies and real cases, many ethical questions are suggested, so reading it is both informative, and reflective.

"The Vital Question" by Nick Lane -Sarah
A fantastic book if you are interested in the history and complexities of evolution. The book looks into how the mitochondria came about with the fusion of prokaryotes and answers some of the most important questions with regards to the development of eukaryotic organisms. I would definitely recommend this book to anybody interested in learning about evolutionary phenomena and the inner workings of cells in different kingdoms.

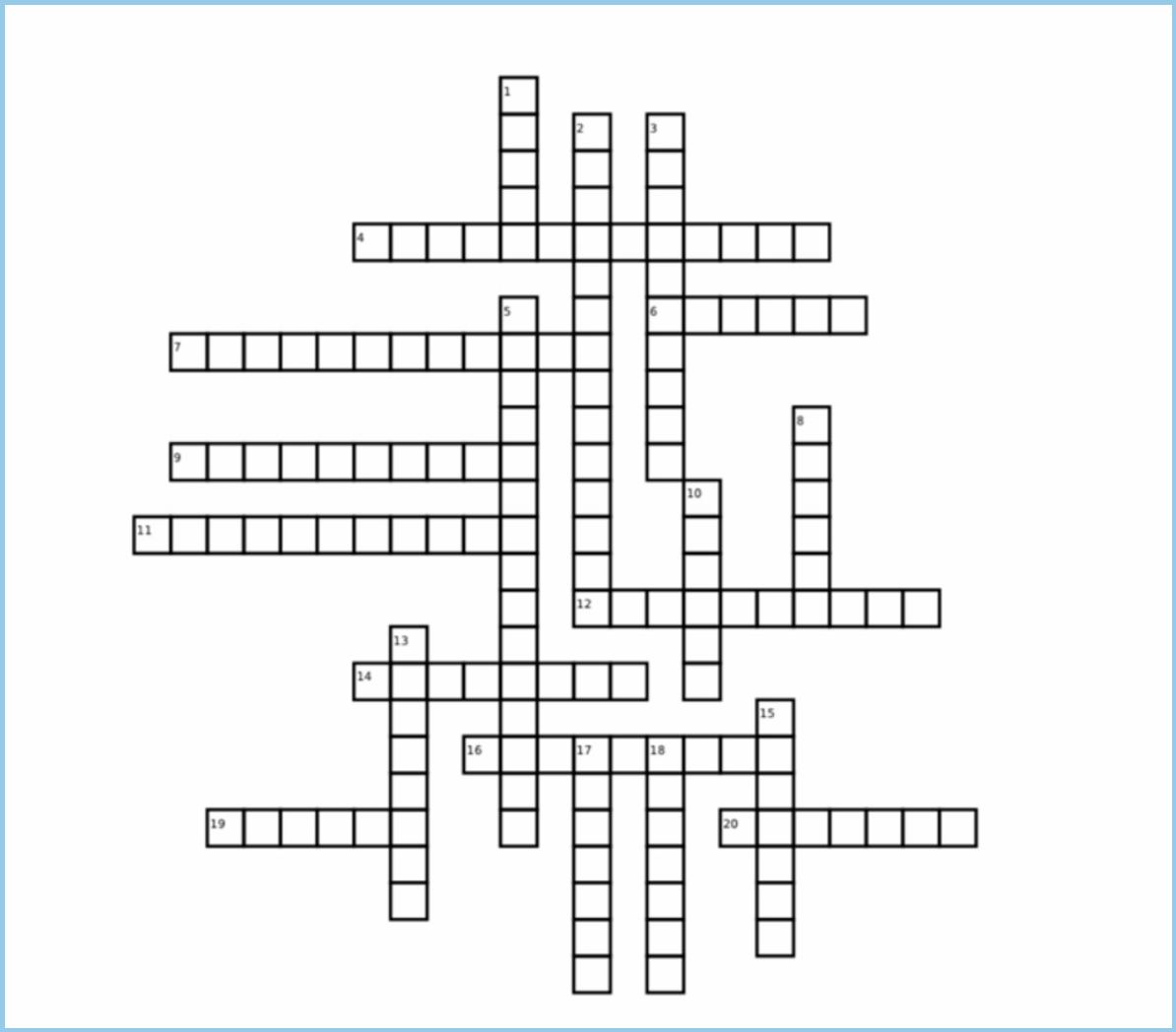
"Outgrowing God" by Richard Dawkins -Saskia
This book provides an accessible (yet detailed) overview of the hypocrisies of various different religions while also explaining the theory of evolution. Dawkins discusses relevant issues and ideas, such as Russell's teapot analogy, proof of evolution, or whether Jesus was actually a nice man, to name a few. If you want to challenge your preconceived notions about society and religion, this book is fantastic!

"Bad Moves" by Barbara Sahakian & Jamie Nicole Labuzetta -Poppy
For anyone interested in mental health and neurosciences, this is a fascinating read on how damage and abnormality in the decision-making areas of the brain can severely affect personality and the ability to manage even simple tasks. Case studies of patients affected by severe depression, Alzheimer's and accidental brain damage are used to demonstrate how pharmacological intervention, by the use of controversial 'smart drugs', can improve cognitive function.

"The Emperor of All Maladies" by Siddhartha Mukherjee -Tati
A book described as a biography of cancer dives into the history of cancer and attempts to understand the ancient disease. I would really recommend for anyone who is interested in medicine, or just cancer! It is a heavy read but overall its fascinating - if its too heavy for you, there is also a documentary version that was made by the author which you can watch - in which they also interview and follow the treatment of some patients - it's also amazing!

Puzzles

Crossword



Down

1. Force carrying particles
2. Chlorophyll contains organisms are...
3. Class of brown algae
5. Steven J Gould/ Ross from friends
8. Open sores
10. The Human [...] project
13. History + ones
15. Who painted the Mona Lisa?
17. No escape from... Mercury
18. Astronomer and Mathematician

Across

4. Treatment of diseases
6. Covid vaccine brand
7. Sydney Farber - Father of
9. Mood is another word for...
11. Removal
12. X shaped
14. Our key to combatting climate change
16. Nervous vomiting and...
19. Algae like plant
20. Movement energy

Sudoku

	6	8	2		1	4		
						2		
			7	6				
1	3							
				8				4
8					2			7
			5	7	4			
		3	6	2	8			
				3				2

Answers

5	6	8	2	9	1	4	7	3
3	1	7	8	4	5	2	9	6
4	9	2	7	6	3	1	8	5
1	3	6	4	5	7	8	2	9
2	7	9	3	8	6	5	1	4
8	5	4	9	1	2	3	6	7
9	2	1	5	7	4	6	3	8
7	4	3	6	2	8	9	5	1
6	8	5	1	3	9	7	4	2

Across
4. Immunotherapy
6. Pfizer
7. Chemotherapy
9. Atmosphere
11. Eradication
12. Chromosome
14. Microbes
16. Diarrhoea
19. Lichen
20. Kinetic

Down
1. Boson
2. Photosynthetic
3. Phaeophyta
5. Paleontologist
8. Ulcers
10. Genome
13. Histones
15. DaVinci
17. Reality
18. Hypatia

Thank you...

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Thanks to everyone who contributed to the first issue of Under the Microscope! We can't wait for you all to join us again for issue 2...

Under the Microscope
Issue 1— Progress— March 2021
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